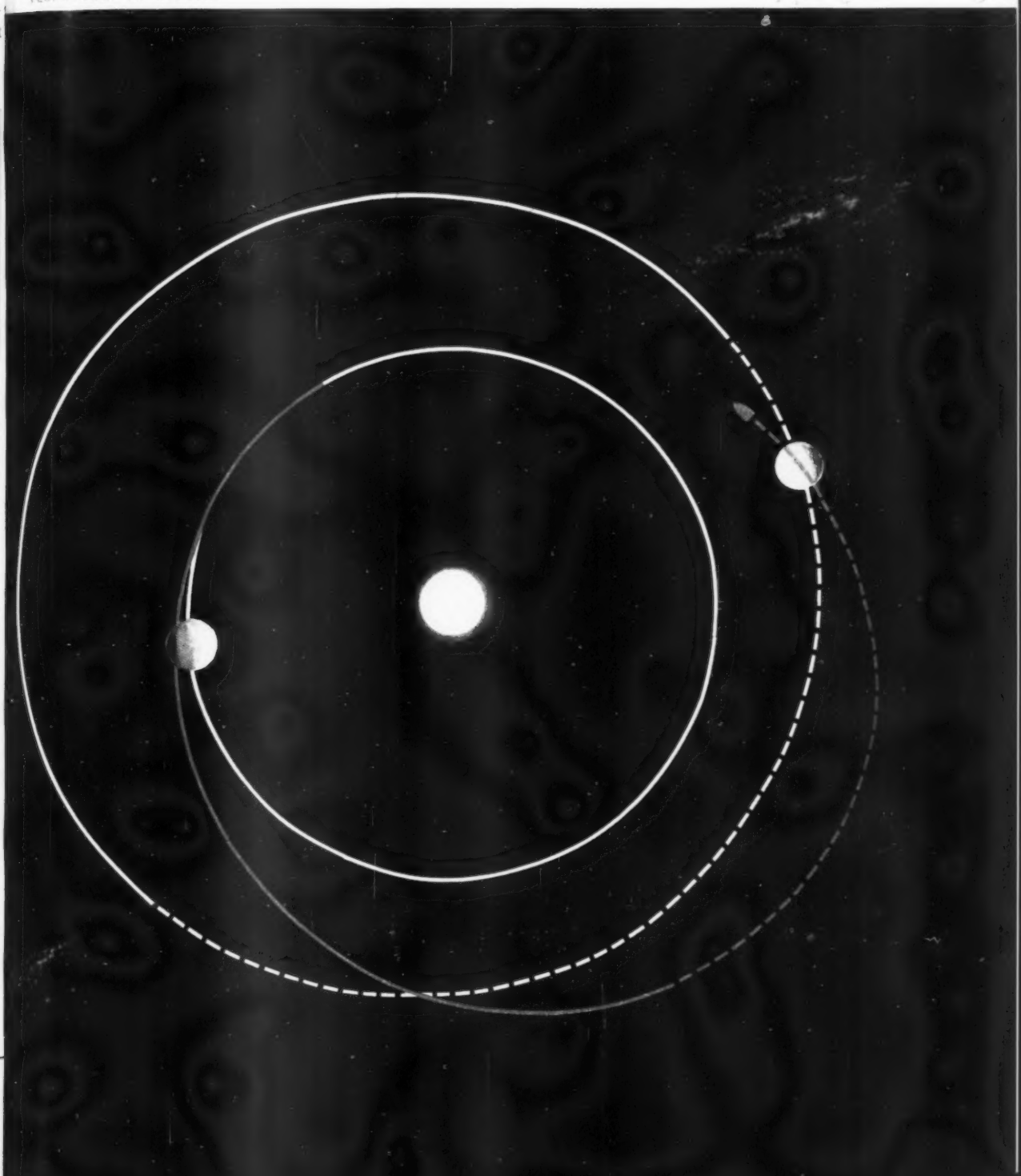
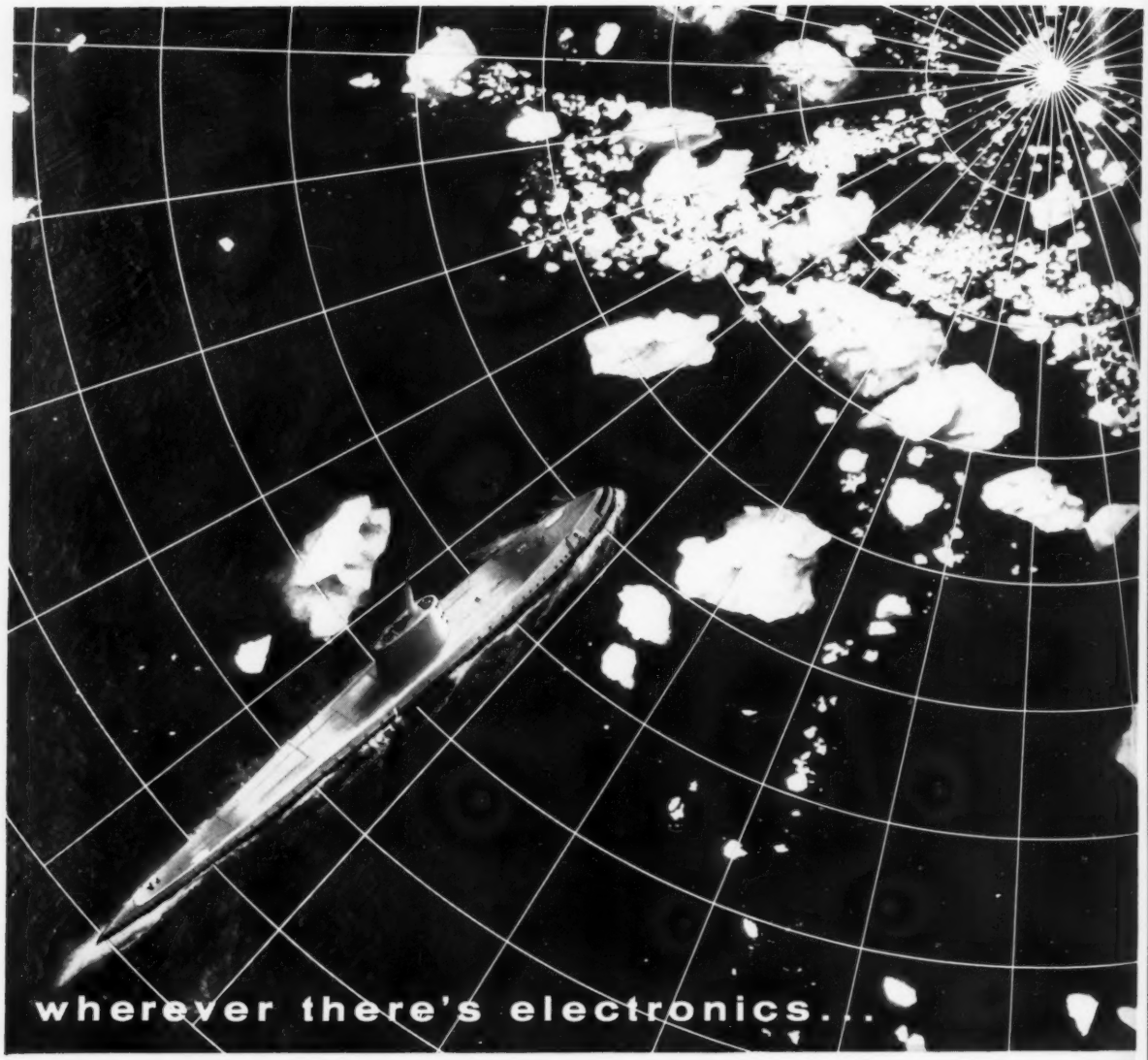
TECHNOLOGY REVIEW

March 1959

TECHNOLOGY DEPARTMENT





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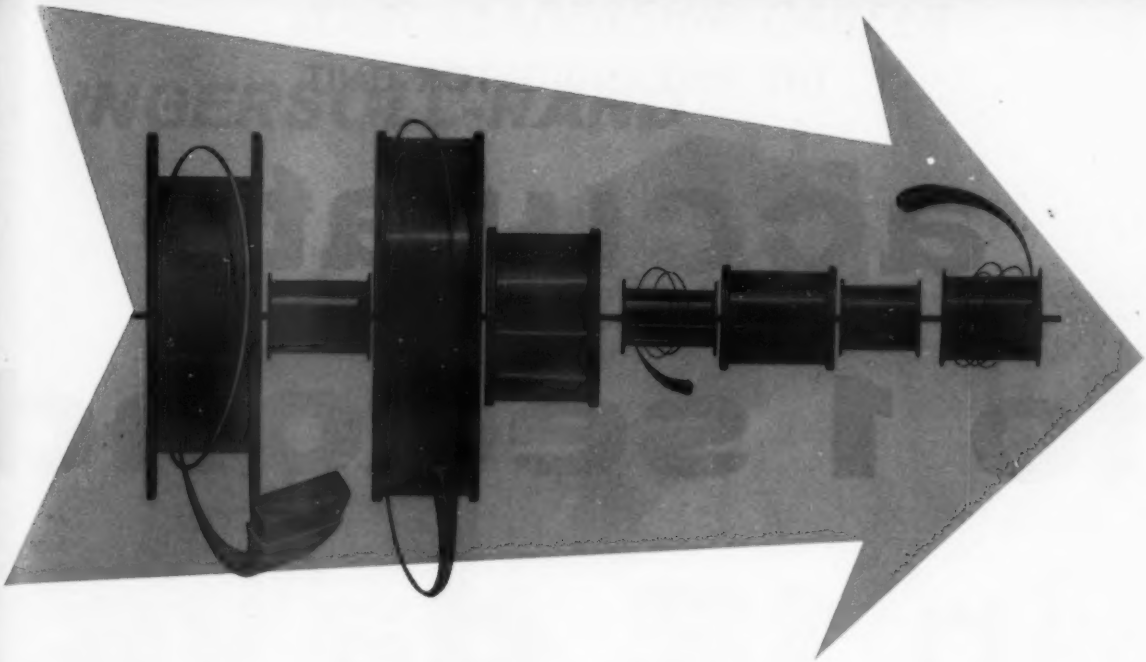

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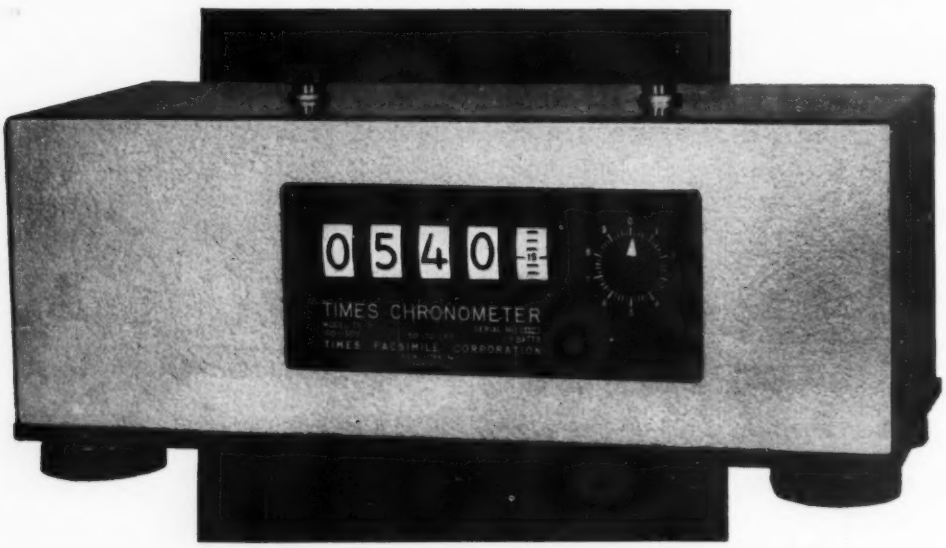

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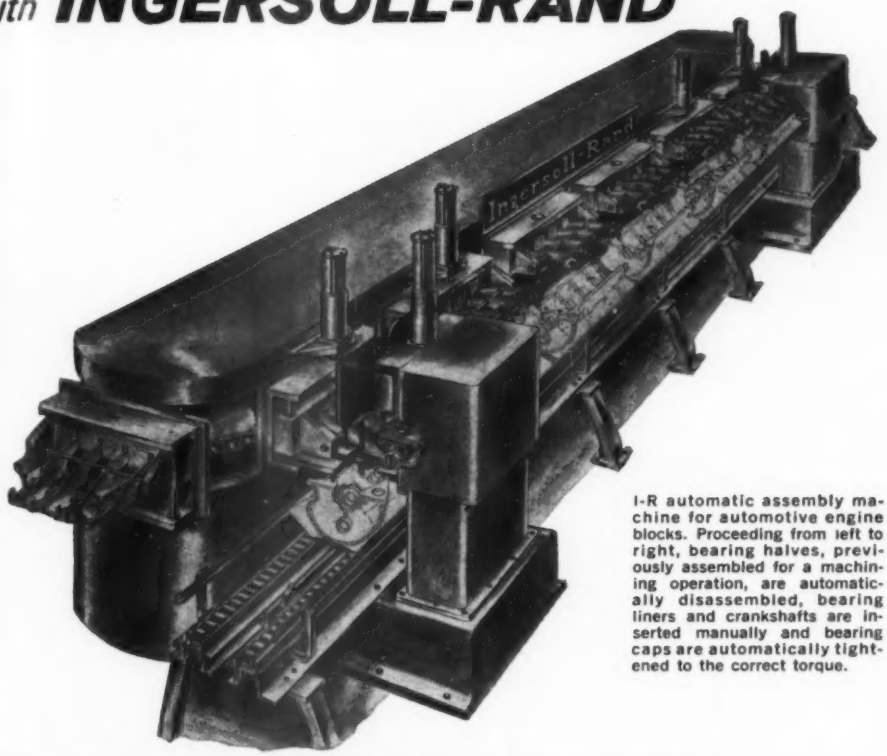
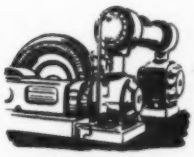


I-R automatic assembly machine for automotive engine blocks. Proceeding from left to right, bearing halves, previously assembled for a machining operation, are automatically disassembled, bearing liners and crankshafts are inserted manually and bearing caps are automatically tightened to the correct torque.

also means **LEADERSHIP** in



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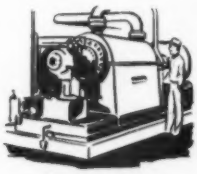
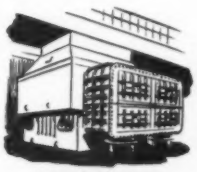
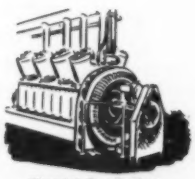


Centrifugal Pumps

Rock Drills



Steam Condensers



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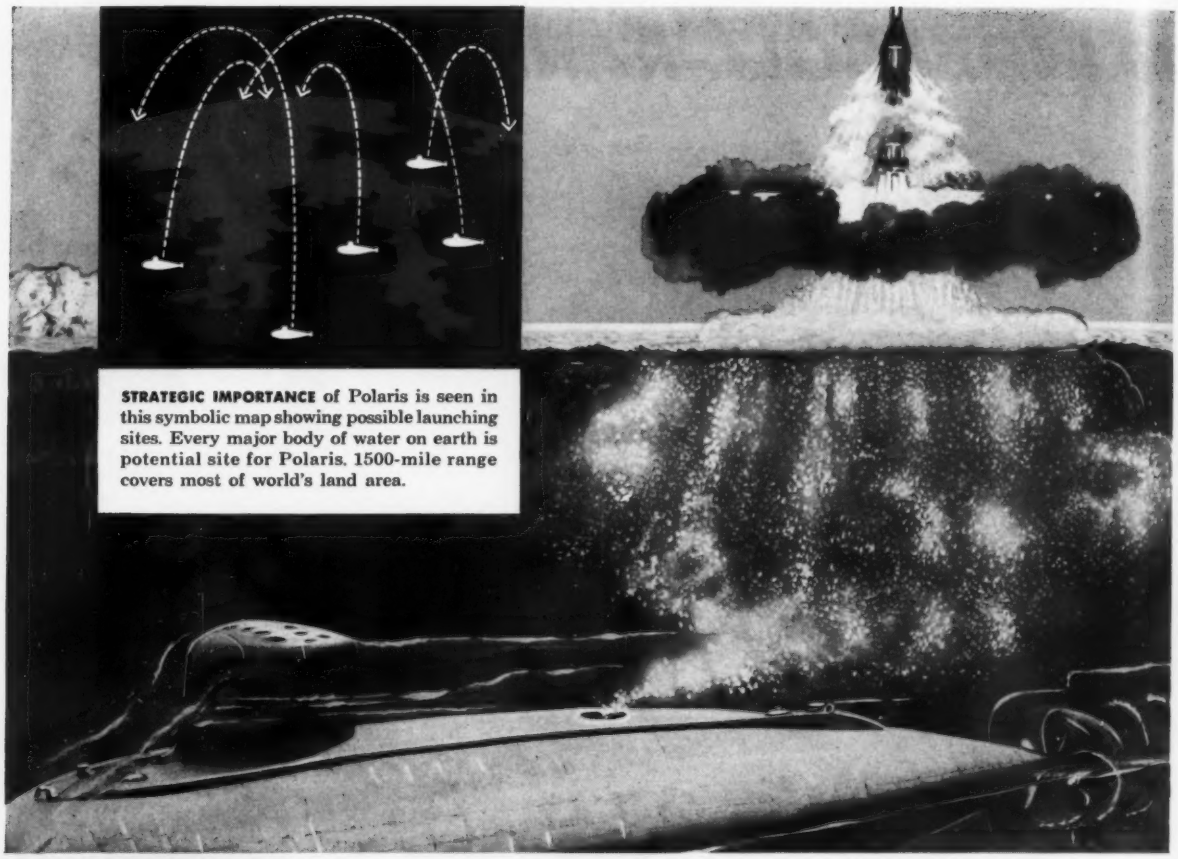
Among the many graduates of Massachusetts Institute of Technology at Ingersoll Rand are: **L. C. Hopton, 1926,** *First Vice-President and Secretary;* **P. J. Bentley, 1925,** *Vice-President.*



STRATEGIC IMPORTANCE of Polaris is seen in this symbolic map showing possible launching sites. Every major body of water on earth is potential site for Polaris. 1500-mile range covers most of world's land area.

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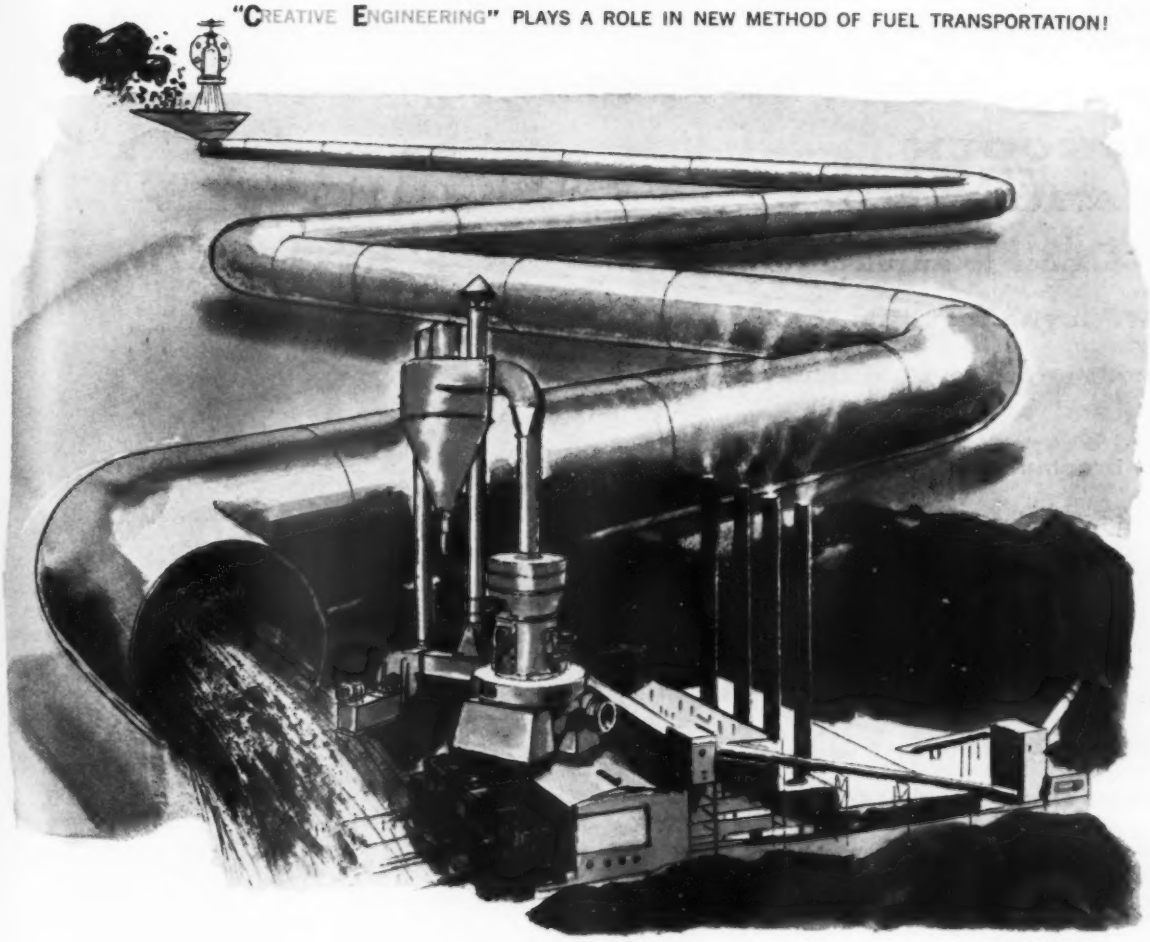

History-making pipeline effects new economies in fuel transportation

The first long-distance coal pipeline in the United States went into regular commercial operation last summer and is now moving coal . . . at a rate of more than 1.25 million tons a year . . . from a mine to a utility power station over a hundred miles away. This history-making pipeline runs from the Georgetown properties of Consolidation Coal Company in eastern Ohio to the Eastlake plant of The Cleveland Electric Illuminating Company near Cleveland. The coal is pumped in the form of a "slurry"—a 50-50 mixture of crushed coal and water.

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THE TABULAR VIEW

"As of February 1." – With the last issue of The Review, BEVERLY DUDLEY, '35, relinquished the editorship, which post he has graced so admirably since 1945, to accept appointment as Assistant to the Director of the Institute's Lincoln Laboratory; and with this current issue VOLTA W. TORREY, since 1956 Director of Television at M.I.T., makes his bow and blush as The Review's 10th Editor. Technically, the transmission of portfolios in each instance occurred as of midnight, January 31.

M.I.T. Photos

B. Dudley, '35 Volta Torrey

A native of Eddyville, Iowa, Mr. Torrey is a graduate of the University of Nebraska's Class of 1926 who later attended the University of Chicago and was a Nieman Fellow at Harvard University. He has been associated with several newspapers, including the Chicago *Tribune*, the Omaha *World-Herald*, the New York *Herald Tribune*, and *PM*. He was formerly news review editor of the Associated Press and a member of the staff of *Popular Science Monthly* for 12 years, five as that magazine's editor. He is a former president of the National Association of Science Writers, and served on the United States Strategic Bombing Survey in 1945.

Mr. Torrey will continue to appear from time to time on "The Science Reporter" program presented by M.I.T. on station WGBH-TV, a program for which he has been host since 1956 when he joined the staff of the Institute's Office of Public Relations to take charge of its television and radio activities.

F. G. Lehmann, '51

Coincident with the change in the editorship of The Review, FREDERICK G. LEHMANN, '51, has been appointed Assistant Secretary of the Alumni Association by its Executive Committee. As an undergraduate, Mr. Lehmann was active in student government, holding official posts therein during his junior and senior years. During 1951-1953, he served as 1st Lieutenant with the U.S. Air Force; during 1953-1954, he was a staff

(Concluded on page 228)

Another Example of Skill With Alloys

Graver's skill with alloys is demonstrated by a long and successful record of fabricating aluminum tank cars for the Union Tank Car Company, North America's largest tank car fleet owner.

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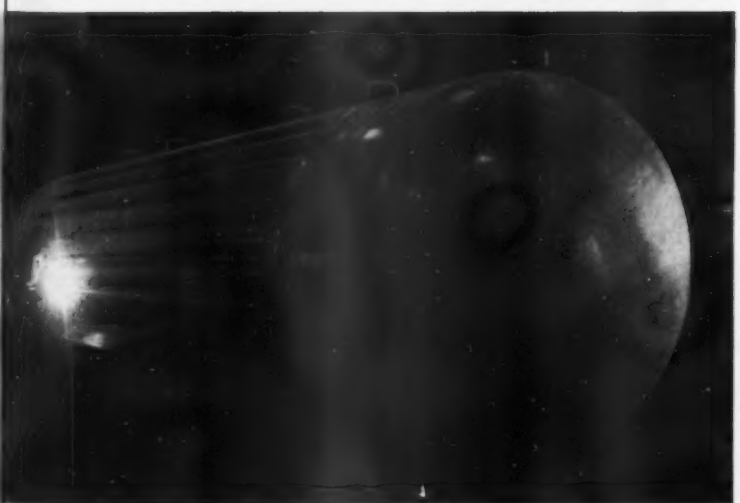

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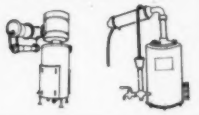

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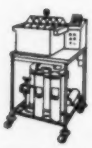

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THE TABULAR VIEW

(Concluded from page 226)

member of the Lincoln Laboratory; and since 1954, he has been associated with the Procter and Gamble Manufacturing Company.

In joining the resident staff of the Alumni Association in Cambridge, Mr. Lehmann relinquishes his office as President of the M.I.T. Club of Kansas City.

H. E. LOBDELL, '17

The Theme Is Space. – As the cover of this issue suggests, the emphasis this month is on the penetration of hitherto inaccessible parts of the solar system. The trajectory to Mars shown on the cover is explained on page 232. Two of the major articles which follow deal with the space age. Defense research in such an age is described by CARL F. J. OVERHAGE (page 239), and the engineering problems of space flight are outlined by H. GUYFORD STEVER (page 244).

Dr. Overhage became director of Lincoln Laboratory two years ago. Born in London, he studied physics at the California Institute of Technology, came to M.I.T. to lead a research group in the Radiation Laboratory, and later became assistant director of the color technology division of the Eastman Kodak Company. He has been active in defense research for many years, and worked in Europe in 1954 on problems related to NATO.

Dr. Stever is professor of aeronautics and astronautics and associate dean of the School of Engineering. He was formerly chief scientist of the Air Force and is now chairman of the Research Advisory Committee on Missile and Spacecraft Aerodynamics of the National Aeronautics and Space Administration. His wide knowledge has brought him a deluge of requests for lectures and interviews.

The articles by Dr. Overhage and Dr. Stever contain the essence of their talks this winter at the Alumni Regional Conference in Detroit, which is described in the Trend of Affairs section (page 237).

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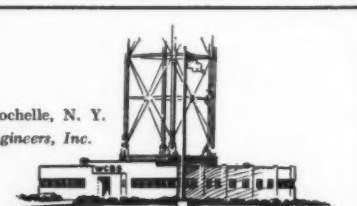

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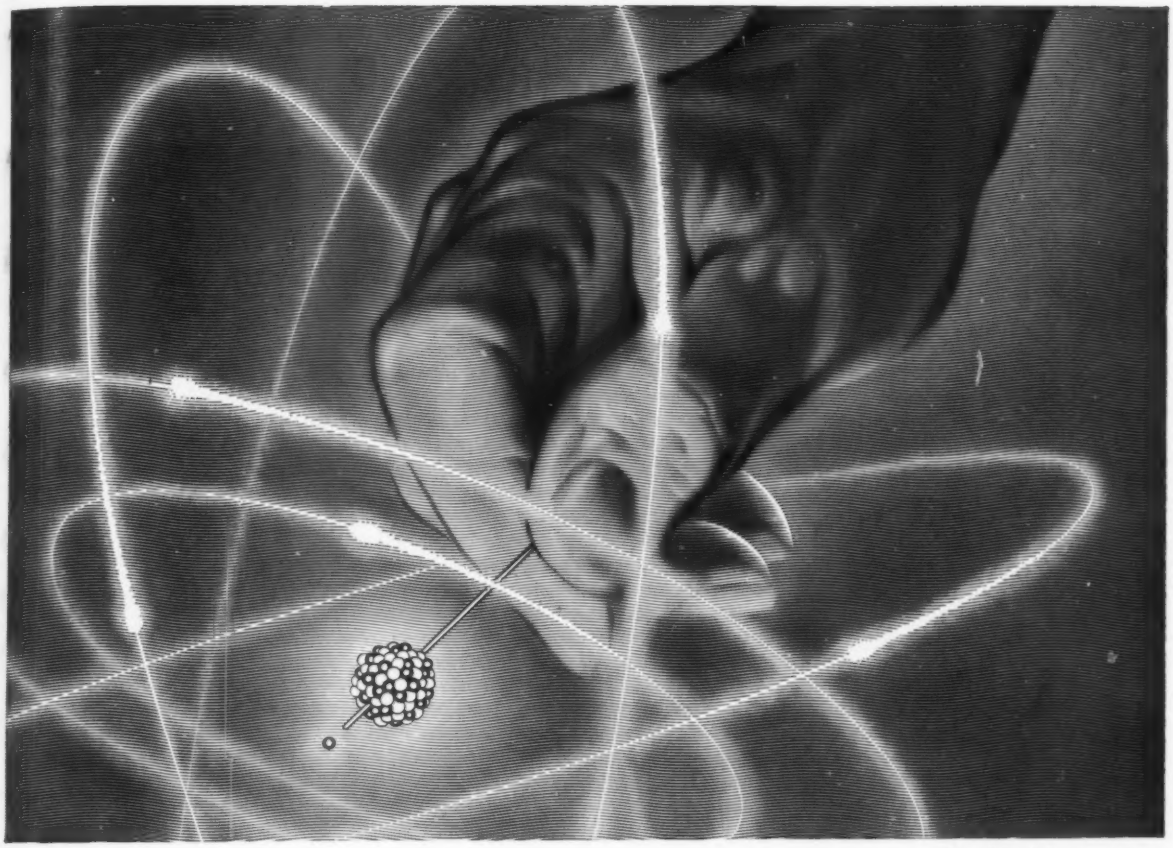

. . . a hand in things to come

Probing the atom...for you

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A longer, healthier life is hopefully ahead as radiation is helping doctors learn more about the basic processes of life by revealing how certain elements are put to work by the body. The controlled rays of the atom are also being used to pin-point malignant tissues for subsequent treatment. And radiation studies of how plants absorb nutrition from sun and soil are showing the way to improved food supplies.

These are but a few of the vital jobs being done by radioisotopes —radioactive materials created in atomic reactors at Oak Ridge, Tennessee . . . the great atomic energy center operated by Union Carbide for the U. S. Atomic Energy Commission. The people of Union Carbide will continue their pioneering research in atomic energy—and in the vital fields of alloys, carbons, chemicals, gases and plastics—to bring you a brighter future.

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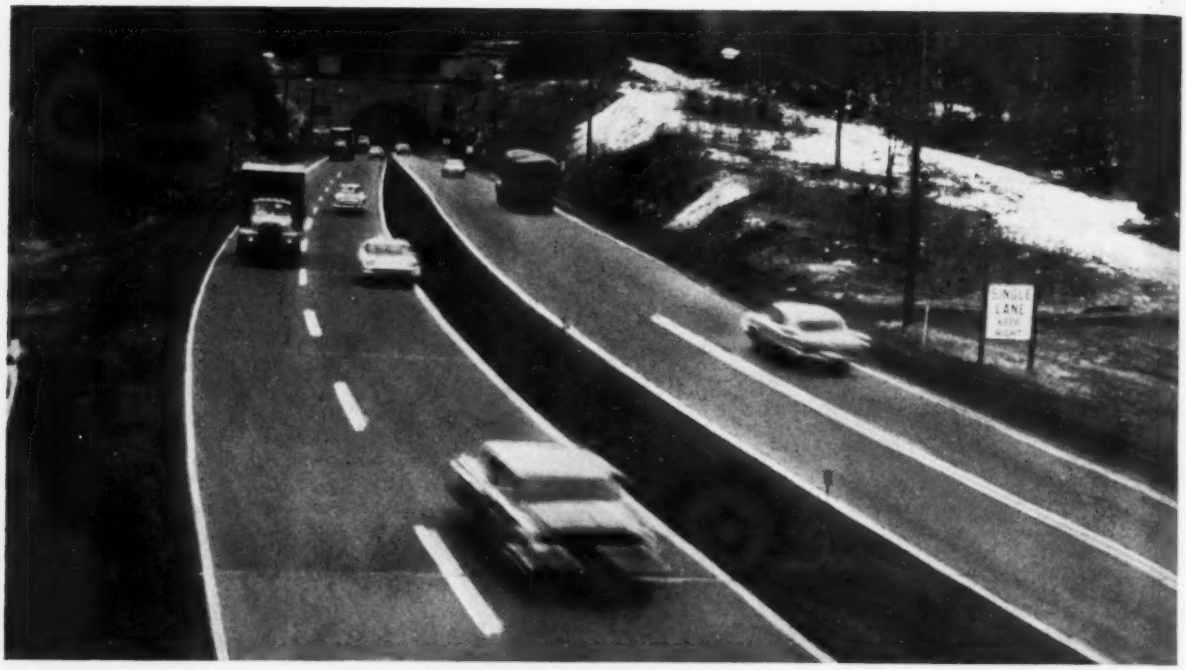

Pennsylvania Turnpike photo, above, was taken at the western end of the 1¼ mile Sideling Hill Tunnel—longest tunnel on the Turnpike.

This year you'll be driving more than ever before on throughways, expressways and turnpikes—at high legal speeds. For greater safety, you need Turnpike-Proved Tires by Goodyear.

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The Technology Review

EDITED AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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The uses and vehicles of space technology are numerous and the engineering problems, such as propulsion and guidance, exceed those in science right now

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Relating to the Massachusetts Institute of Technology

Professor Clifford G. Shull is seen below adjusting the mount on which a sample of material will be studied with a beam of neutrons from the new M.I.T. Nuclear Reactor. Kneeling beside the neutron diffraction spectrometer attached to the reactor is Rolf Soderstrom, a guest of the Institute.

M.I.T. Photo

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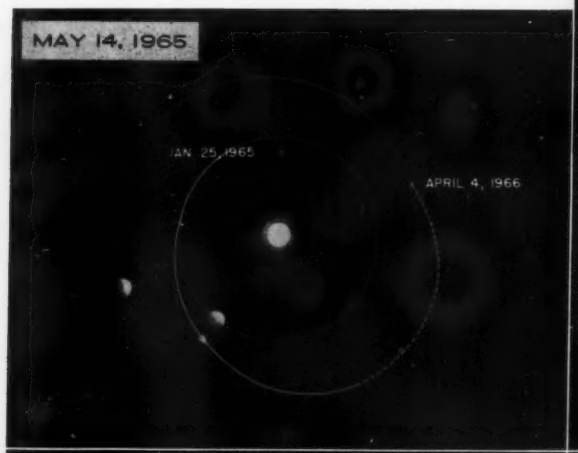
Three weeks must be allowed to effect change of address, for which both old and new addresses should be given.



From Earth to Mars

A NEW technique for determining round-trip planetary reconnaissance trajectories was described recently for the Institute of the Aeronautical Sciences by Richard H. Battin, '45, of the Instrumentation Laboratory at M.I.T.

The two pictures above show the outbound path of an instrument-carrying spaceship, launched from earth with a relative velocity of 9,400 miles per hour on January 25, 1965, into a freefall orbit about the sun. Contact with Mars would be made on April 4, 1966, when the vehicle passed within about 5,000 miles of its surface. The relative orientation to Mars, as indicated in the upper right-hand corner, must be carefully controlled since the Martian gravitational field would alter the course. If the maneuver is properly executed, the ship would return to earth on March 24, 1968, without additional propulsion.

The other pictures at the right show various stages of the return trip. Solid lines indicate when Mars and the spaceship would be in orbital planes above the plane of the earth's orbit; broken lines indicate when the orbits of Mars and the ship would be in planes below that of the orbit of the earth. Conditions for a reconnaissance mission such as this prevail during an interval of several months and recur approximately every two years.

The Technology Review

VOL. 61, NO. 5 MARCH, 1959

The Trend of Affairs

From Great to Puny Brains

■ George R. Harrison, Dean of the School of Science, has dubbed those amazingly fast and helpful digital computers that International Business Machines Corporation and other concerns are producing "great big puny brains." If you want a tool to produce a certain part for an airplane, a computer can tell it how its cutting edge must be guided. Computers have done this many times, on many jobs, since Whirlwind I first ran a milling machine at M.I.T. seven years ago. But telling a computer what you want it to tell a machine tool is a tiresome, time-consuming chore – because even the biggest, fastest, most versatile electronic computers are "puny" brains. They must be carefully "programmed."

So a new language has been devised to simplify telling a computer what directions it must give to a machine tool when you want it to carve out a new part. This language consists at present of only 100 words, none of which contains more than six letters. It is a key part of a system called APT, which is a means of "Automatic Programming of Numerically Controlled Machine Tools."

Perhaps you already have read in your newspaper or trade publication about APT. Reporters flew to M.I.T. from New York and Washington in February to learn about APT, see it demonstrated, and attempt to describe it in language that people could understand. (This, too, is quite a trick.)

The APT vocabulary is easy to learn. Suppose, for instance, that you wanted the coolant turned on and the spindle of a tool started. In APT, you would simply write "ON KUL, ON SPN." Then, if you wanted the tool guided to the right on the left side along a circle, the center of which was where X equaled 2 and Y equaled 3, and the radius of which was 5, you could write (in APT) "GO RGT, TL LFT, CIRCLE/CTR AT, + 2, +3, RADIUS, 5." This is good enough language for a puny brain. When given such instructions, in this way, a computer can make the calculations and prepare the magnetic tape required by an automatic machine tool.

The APT system, of which APT language is only a newsy part, was based on research supported by the Air Force in the M.I.T. Servomechanisms Laboratory. The Aircraft Industries Association has sponsored development of this system and is enthusiastic about it not only because it saves man-hours but also because it can bring about industry-wide compatibility and has been purposely designed for future growth and expansion.

A computer-programming assignment that formerly would keep a man busy for 200 hours now can be done the APT way in five hours. But the M.I.T. laboratory's staff consider what has been done thus far only an initial breakthrough. "Continued co-operative development of the APT concept by the aircraft industry," says Douglas T. Ross, '54, head of the computer-applications group, "will lead to increased productivity from numerical-control applications, and can influence many industrial processes."

The Ballots Are Ready

■ Ballots will be sent this month to the Alumni of M.I.T. for their use in electing officers of the Alumni Association for the year beginning next July 1. Three alumni term members of the M.I.T. Corporation will be proposed at the same time. The nominees are:

Edward J. Hanley, '24, to be president of the Alumni Association for one year;

William L. Taggart, Jr., '27, to be vice-president of the Association for two years;

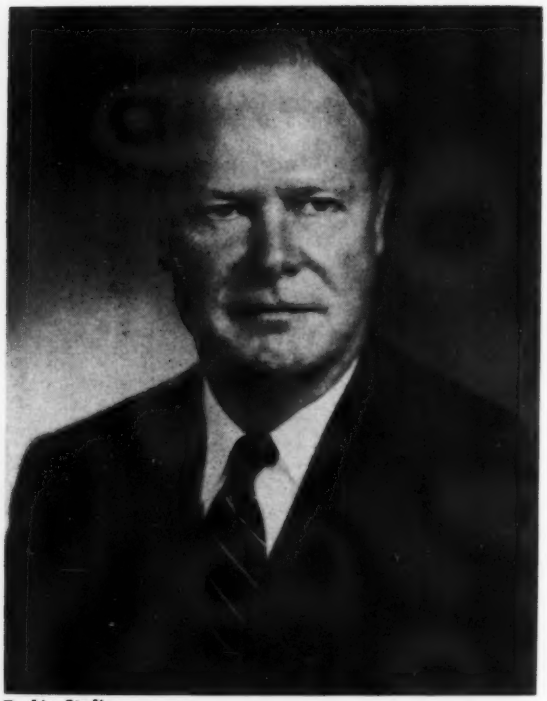
Henry B. Backenstoss, '34, and *Albert O. Wilson, Jr., '38,* to be members of the Executive Committee of the Association for two years;

William Webster, '23, John J. Wilson, '29, and *James B. Fisk, '31,* to be alumni members of the M.I.T. Corporation for five years.

All of these men have worked previously in other capacities to advance the interests of the Institute. Portraits of Mr. Hanley, who is the sole nominee for the presidency of the Association, and the three nominees for alumni term membership on the M.I.T. Corporation are on the next page. One of the latter, Mr. Wilson, is serving now as the Alumni Association's 65th president and on the Corporation's Visiting Committees on Student Activity and on the Medical Department.

Messrs. Webster and Fisk have both distinguished themselves professionally and served their country in

Nominated for the Presidency of the Alumni Association



Deakin Studio

. . . Edward J. Hanley, '24, II, who has been nominated for the presidency of the M.I.T. Alumni Association, is president of the Allegheny Ludlum Steel Corporation in Pittsburgh. He is also a director of this company and of the Titanium Metals Corporation of America, the Duquesne Light Company, the Westinghouse Air Brake Company, the Mellon National Bank and Trust Company, the Mine Safety Appliances Company, the Bell Telephone Company of Pennsylvania, and the American Iron and Steel Institute.

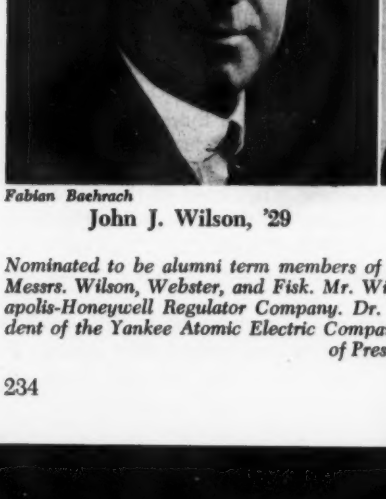
Mr. Hanley is a 1956-1961 alumni term member of the M.I.T. Corporation, and also has served the Institute and its Alumni in other roles for nearly three decades. He was president of the M.I.T. Club of Schenectady in 1930-1931, and a member of the Board of Governors of the M.I.T. Club of Western Pennsylvania in 1954. He has been on the Visiting Committee on the Department of Metallurgy since 1956, and its chairman for the last two years. He also was on the Visiting Committee on the Department of Chemical Engineering in 1956-1957, and is now a member of the Advisory Council of the School of Industrial Management.

His office is on the 20th floor of the Oliver Building in Pittsburgh, and his home is in Allison Park, Pa. He is a member of the Iron and Steel Institute (London), the Association of Iron and Steel Engineers, the National Association of Accountants, the Controllers Institute of America, and The Newcomen Society of North America. His clubs include the Duquesne and the Union League Club (New York).

important roles. Dr. Webster has been associated with the Department of Defense in matters regarding atomic energy, and research and development; he also has served on the National Advisory Committee for Aeronautics and the Army Scientific Advisory Panel. Dr. Fisk was director of the Division of Research in the U.S. Atomic Energy Commission, and a member of the General Advisory Committee of the commission, before being named to the President's Science Advisory Committee.

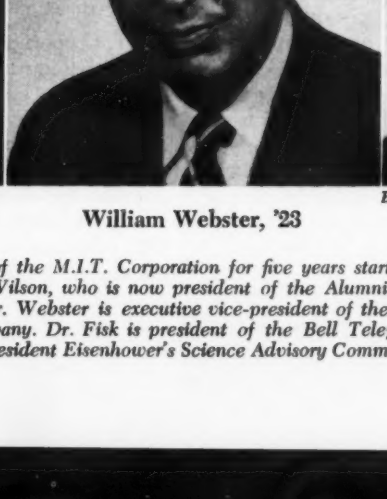
Mr. Taggart, the nominee for the vice-presidency of the Alumni Association, is executive vice-president of Dewey and Almy Chemical Company (Division of W. R. Grace and Company) in Cambridge, and is chairman of the 1959 Alumni Day Committee.

One of the nominees for election to the Executive Committee of the Association, Mr. Backenstoss, is project manager for Jackson and Moreland, Inc., in Boston; and the other, Mr. Wilson, is president and treasurer of the A. O. Wilson Structural Company.



Fabian Bachrach

John J. Wilson, '29



William Webster, '23

Bell Telephone Laboratories

James B. Fisk, '31

Nominated to be alumni term members of the M.I.T. Corporation for five years starting July 1, 1959, are (from left to right) *Messrs. Wilson, Webster, and Fisk. Mr. Wilson, who is now president of the Alumni Association, is a director of the Minneapolis-Honeywell Regulator Company. Dr. Webster is executive vice-president of the New England Electric System and president of the Yankee Atomic Electric Company. Dr. Fisk is president of the Bell Telephone Laboratories, Inc., and a member of President Eisenhower's Science Advisory Committee.*

The present membership of the National Nominating Committee includes: John A. Lunn, '17, chairman, Philip L. Alger, '15, Edmund D. Ayres, '22, Cecil H. Green, '23, Max L. Ilfeld, '24, Hartselle D. Kinsey, '24, Ralph B. Johnson, '27, Jean M. Raymond, '34, Bissell Alderman, '35, and Henry Avery, '41.

This year's ballots also will carry the names of the following nominees (with one Alumnus to be elected from each District) to be representatives for three years on the National Nominating Committee: *District 8* – San Juan, Puerto Rico – Antonio S. Romero, '12; Havana, Cuba – Antonio H. Rodriguez, '21; Knoxville, Tenn. – George P. Palo, '28; Oklahoma City, Okla. – Charles B. Stuart, '34; – *District 9* – Kansas City, Kansas – William R. Wheeler, '25; Duluth, Minn. – Arthur C. Josephs, '28; – *District 10* – Portland, Ore. – E. Robert deLuccia, '27; Seattle, Wash. – Jacob A. Samuelson, '40.

The following classes, whose numerals end in five or zero, also will vote for representatives to serve for five years on the Alumni Council: 1895, 1900, 1905, 1910, 1915, 1920, 1925, 1930, 1935, 1940, 1945, 1950, 1955.

Individuals Noteworthy

■ Prominent in the news since the advent of 1959 have been the 34 promotions, elections, or appointments enumerated below:

Frank M. Carhart, '05, as Chairman of the Board; *Ralph D. Booth, '20,* as President; *John R. Coffin, '17,* as a Senior Vice-president; and *Henry W. Hills, '20, Alexander J. Tigges, '23, Leo J. Myskowski, '28,* and *Arthur Y. Taylor, '46,* as Vice-presidents, Jackson and Moreland, Inc.;

Whitworth Ferguson, '22, as a Director, Buffalo Branch, Federal Reserve Bank of New York . . . *Robert C. Sprague, '23,* as Chairman of the Board, Federal Reserve Bank of Boston . . . *George J. Leness, '26,* and *William A. Forrester, Jr., '26,* respectively, as Chairman of the Executive Committee and as a Director, Merrill, Lynch, Pierce, Fenner, and Smith;

David A. Shepard, '26, as Executive Vice-president, Standard Oil Company of New Jersey . . . *Nathan Cohn, '27,* as Vice-president – Technical Affairs, Leeds and Northrup Company . . . *Henry G. Houghton, '27,* as Council member, American Meteorological Society;

William J. Kirk, '28, as President, John P. Chase, Inc., investment counsel, Boston . . . *Alfred T. Waidelich, '30,* as Director of Engineering and Research, the Austin Company, Cleveland . . . *Donald A. Holden, '31,* as Vice-president and Production Manager, Newport News Shipbuilding and Dry Dock Company;

Thomas E. Sears, Jr., '32, as President, Thomas E. Sears, Inc., Boston . . . *Harner Selvidge, '32,* as President, Soaring Society of America . . . *Richard M. Stewart, '32,* as a Director, Bullard Company, Bridgeport, Conn. . . . *David B. Smith, '33,* and *Donald G. Fink, '33,* respectively, as Vice-president for Technical Planning and as Director of Research, Philco Corporation;

Beaumert H. Whitton, '33, as President, Southeastern Construction Company, Charlotte, N. C. . . . *Edward W. Comings, '34,* as Dean of Engineering, University of Delaware . . . *Robert F. Flood, '35,* as Vice-president, Linde Company Division, Union Carbide Corporation;

On the Horizon

March 12–14, 1959 – 11th Annual Fiesta, M.I.T. Club of Mexico, Mexico City, D.F. (For reservations, consult Clarence M. Cornish, '24, Margaritas 257, Villa Obregon, Mexico 20, D.F., Mexico.)

June 15, 1959 – 25th Alumni Day, 1959. M.I.T. Campus in Cambridge.

Henry C. Johnson, '36, as Chairman of the Board and President, Phil Wood Industries, Ltd., Windsor, Ont. . . . *Franklin S. Atwater, '38,* and *Harold M. Brodsky, '47,* respectively, as Vice-president – Manufacturing and as Manufacturing Manager of Branch Plants, Fafnir Bearing Company, New Britain, Conn.;

William S. Brewster, '39, as Vice-president, United Shoe Machinery Corporation . . . *Rodrigo Uribe, '41,* as *Ministro Consejero* of the Embassy of the *República de Colombia* to the United States . . . *S. James Spitz, Jr., '43,* as Vice-president, Newport Industries, Inc., Pensacola, Fla.;

Gunther H. Baldauf, '44, as Research Manager, Allied Paper Corporation . . . *Lester Simon, '44,* as Vice-president, R. A. Ransom Company, Inc., Portland, Maine . . . *Melvin E. Salveson, '47,* as President, the Institute of Management Sciences.

■ Special honors recently announced or awarded to Alumni and members of the Faculty include:

To *William L. Stewart, Jr., '23,* the Trans-Oceanic Pennant, by the Cruising Club of America . . . to *Charles S. Draper, '26,* and *Robert G. Loewy, '48,* respectively, Honorary Fellowship and the Lawrence Sperry Award, by the Institute of the Aeronautical Sciences;

To *Doyle L. Northrup, '31,* the Distinguished Federal Civilian Service Award, by President Eisenhower . . . to *James G. Potter, '33,* its Distinguished Service Citation, by the American Association of Physics Teachers.

The Complete but Gentle Squelch

■ When Harold E. Edgerton, '27, Professor of Electrical Measurements at the Institute, was named Outstanding New England Engineer of 1958, press photographers visited his laboratory and asked him to show them how to stop a bullet photographically. Again and again and again in a darkened room, Dr. Edgerton held a balloon in front of a rifle while an aide fired a bullet through it into the end of a pipe full of sand. Each shot triggered a light that flashed on for 1/2,000,000th of a second. Bullets were caught entering, inside, and coming out of the balloons. "Got it?" the weary doctor asked at long last. "One more, please," said the photographers from force of habit. So another balloon was burst. This time a sharp ping followed the gun's bark. Did the bullet ricochet into the room off the pipe's end? No one asked for another shot. . . . In a far corner, one of Dr. Edgerton's friends had tapped a bit of metal with a hammer. That broke the habit.

Permanent Office for Religious Counselors

■ The importance of religion in the lives of students, Faculty, and staff at the Institute has long been recognized. When the student body was smaller than it is today and a larger percentage of students were commuters, the spiritual and religious needs of the Technology community were administered entirely by the churches in Boston and vicinity. Since the 1940's, however, religious counselors have been available on campus.

At the close of World War II, more students than ever before sought higher education. A large number were veterans and many were married and had families. Among this mature group there was a strong urge to seek meaning in life. The concept of technical education was being broadened in recognition of the fact that the uses to which technology was being put were of concern to those who would advance science and engineering in their professional work.

As M.I.T. became increasingly a residential college, the M.I.T. Chapel was built and the part-time counselors found their services to be in ever-expanding demand. In thus broadening higher education, the Institute has made its own contribution to the development of the student's total experience.

Frequently the religious counselors are called upon to help students solve emotional or other personal problems, for many students find themselves away from home for an extended period for the first time in their lives, or may have difficulty adjusting to college life. Although performing a distinctly different function, the religious counselors frequently work closely with the Institute's Faculty advisers, the Deans, and the personnel in the Medical Department. The services of these counselors had assumed such magnitude and importance by last year that more adequate office quarters in the residential area of the M.I.T. campus seemed desirable.

Another important step was taken, therefore, to make religious counseling more readily available. The Institute acquired a private dwelling at 317 Memorial Drive, a short distance west of Massachusetts Avenue, and converted this four-story structure into a permanent headquarters for the religious counselors. Furnishings for the new center were provided by the Advisory Board of the Technology Community Association, and each room is quietly and tastefully decorated.

The Reverend J. Edward Nugent, religious counselor for Catholic students, Rabbi Herman Pollack, counselor for Jewish students, the Reverend Robert C. Holtzapple, Jr., counselor for Presbyterian and Congregational students, and the Reverend Myron B. Bloy, Jr., counselor for Episcopal students, have offices in the new headquarters. These men spend their full time at M.I.T. A dozen other religious counselors also have stated office hours, and an even larger number are available on call. They, too, on a part-time basis, share in the facilities provided by the new building.

Many different religious services are held in the M.I.T. Chapel regularly, and it is open daily for private meditations.

This is the reception room of the Institute's new headquarters for its religious counselors, at 317 Memorial Drive, a short walk from Massachusetts Avenue and the main M.I.T. building.

Three secretaries are kept busy handling the details of counseling for Institute students in this office adjacent to the reception room. The window overlooks the Charles River.

M.I.T. Photos

The religious counselors have private offices on the second and third floors of the recently renovated four-story building. The study shown here is used by the counselor to Catholic students. There is also a seminar room. Thus appropriate facilities have been provided for friendly discussions of the religious problems of young people preparing for their careers. The counselors work closely with the Faculty and the deans.

The Charles River Basin Project

■ Fifty-six years ago the Massachusetts legislature authorized a dam in the Charles River to eliminate unsightly mud flats, and create between Boston and Cambridge a beautiful expanse of water such as few cities in the world enjoy. The Charles River Basin is a front yard of priceless value for the whole area and this setting was a major consideration in the planning of the M.I.T. buildings.

But 40 acres of the river bottom on the Cambridge side, which had remained in private ownership when the basin was created, now belong to John Briston Sullivan, a Cambridge real estate man, who decided that he could erect, on stilts driven into the mud, a multimillion dollar commercial development. He has a bill in the legislature to shift jurisdiction of the area from the Metropolitan District Commission, which wants to keep the Charles River Basin for public use, to the City of Cambridge, which could rezone the land for industrial use.

Buildings covering the 40 acres would extend nearly halfway across the river from the Cambridge shore, ruining the vista. They would stretch up the river from the Longfellow Bridge past part of M.I.T. Needless to say, M.I.T., Arthur D. Little, Inc., and other neighbors, as well as all citizens who are interested in preserving the area, are opposed to the bill and are expressing their opposition in letters to their legislators and newspapers.

"This is as much the public domain as the Grand Canyon or Yellowstone National Park," said Louis M. Lyons in a newscast on WGBH-TV. "It would be immoral to give to a private commercial interest the right to take it away from the people for whom it was created."

The area shown in white is the portion of the Charles River Basin which the Institute and others have rallied to defend.

At the Institute This Summer

■ The 1959 Summer Session at M.I.T. will attract more than 3,000 students. About half of them will be supplementing fall and spring work; the others will be professional visitors, updating or refreshing their knowledge of specialties. The latter will bring on-the-job knowledge and experience which is greeted with enthusiasm at the Institute. Most of them will take intensive short courses (running from one to three weeks), about which more may be learned by writing to Professor James M. Austin, '41, Director of the Summer Session. These special courses this summer will deal with important aspects of:

Adhesion: Theory and Practice (Building Engineering)
Aesthetics of Surfaces (Architecture)
Bearing Technology (Mechanical Engineering)
City and Regional Planning
Controllership (Industrial Management)
Corrosion (Metallurgy)
Direct Conversion of Heat to Electricity
Finite- and Infinite-State Machines
Food Protection Factors (Food Technology)
Industrial Dynamics (Industrial Management)
Industrial Photoelasticity (Mechanical Engineering)
Infrared Spectroscopy (Chemistry)
Institutional Expansion (City and Regional Planning)
Long-Range Radio (Electrical Engineering)
Marketing Strategy and Tactics (Industrial Management)
Materials for Parachutes (Mechanical Engineering)
Mechanical Properties of Plastics
Modern Thermodynamics (Mechanical Engineering)
Organization for Research (Industrial Management)
Plasma Dynamics (Physics)
Probability Theory Applications (Operations Research)
Quantitative Approaches to the Study of Neuroelectric Activity (Electrical Engineering)
Scientific and Engineering Reports (Humanities)
Shear Strength of Soils (Civil Engineering)
Strain Gauges (Mechanical Engineering)

From Missiles to Schools

■ Detroit engineers showed visitors from M.I.T. a new kind of industrial plant, and Julius A. Stratton, '23, President of M.I.T., sketched a new kind of education for them, when about 500 Alumni and friends of the Institute met on January 31 for a Regional Alumni Conference. Arranged by the Detroit M.I.T. Association, it brought scientists, industrialists, engineers, and educators together to consider the future of atomic power, space flight, defense laboratories, and the democratic process.

Thomas F. Morrow, '35, Vice-president of the Chrysler Corporation and chairman of the committee responsible for the gathering, gave his guests from Cambridge a preconference tour of a 2,100,000-square-foot missile factory. Owned by the U.S. Army but run by auto makers, this plant was built to turn out jet engines. Instead, its 11,000 employees and long assembly lines now mass produce those gigantic arrows called Redstones and Jupiters. C. Allan Brady, general manager of this great array of tools, jigs, and testing instruments, and his assistant B. J. Meldrum, showed the deans and professors how up to 300,000 parts are welded, tucked, and intricately linked together in many modern ways to become complete ballistic missile systems.

At the Detroit missile plant (from left to right): John J. Wilson, '29, of Boston; Donald Dresselhouse and B. J. Meldrum of Chrysler Corporation; and Dean Burchard.

At the Detroit Alumni Conference (from left to right): W. D. J. MacDonnell, '34, of the Great Lakes Steel Corporation; President Stratton; and Mr. Wilson.

Dr. Stratton, the next evening, spoke of the upheaval in engineering education that has resulted from scientific discoveries and the acceleration of industrial progress. The immensity of both of these forces had been everywhere apparent in the missile plant. "Science on the one flank, and industry on the other," the Institute's president said, "are setting the pace." Changes are being considered, consequently, both in the curricula and in the approach to the education of an engineer.

Dr. Stratton reviewed four movements – the expansion of the frontiers of science, the deepening of the theoretical base of engineering, the fusion of fields of engineering, and the increasing importance of research – which have reverberated through the classrooms. "Getting an education at M.I.T.," he was told by one student, "is like getting a drink from a fire hose." Nevertheless, Dr. Stratton concluded, "With all our groping, I think that we shall find a proper balance for the future."

The keynote of the Detroit conference had been sounded earlier by George R. Harrison, Dean of the School of Science. Since the first Sputnik went up, he reported, the curricula in more than one-fourth of our high schools have been changed for the better. Now the Russians' Lunik 1 has provoked us again into giving more attention to science.

Dean Harrison's anecdotal survey of science and its future prompted one auditor to say, "They've put their best hitter up first"; but more hits came throughout the day. Professor Theos J. Thompson, Director of M.I.T.'s Nuclear Reactor, was the second man up, and he scored by describing and answering questions about the nuclear power reactors and the nuclear research with reactors that is under way in Michigan, Massachusetts, and Pennsylvania.

H. Guyford Stever, Professor of Aeronautics and Astronautics, then listed the engineering problems of space flight, and Carl F. J. Overhage, Director of Lincoln Laboratory, showed pictures of the laboratory and discussed defense research in the space age. Articles based on their addresses appear elsewhere in this issue of The Review.

Democracy's future, John E. Burchard, '23, Dean of the School of Humanities and Social Studies, maintained in the afternoon's final address, depends on the citizen's ability to ask the right questions and participate in debate about problems vital to the nation. The liberal arts colleges, he suggested, should see to it that educated men and women are aware of the problems of scientists – for the same reason that schools such as M.I.T. now require prospective scientists and engineers to study the humanities and social sciences.

Charles A. Chayne, '19, Vice-president of General Motors, was moderator of the morning session, and James C. Zeder, Vice-president of Chrysler Corporation, introduced the speakers in the afternoon. Then Robert B. Semple, '32, President of the Wyandotte Chemicals Corporation, presided while all of the speakers sat as a panel and dealt with questions from the floor.

W. D. J. MacDonnell, '34, President of the Great Lakes Steel Corporation, was toastmaster at the banquet which followed, and John J. Wilson, '29, President of the Alumni Association, spoke briefly about the Association's activities, before President Stratton related the day's remarks to the education of future engineers.

In the lobby between sessions and at the reception preceding the banquet, there was much talk of small-versus-large cars – and laughter as space-age stories were told. A favorite was the one about two Russian scientists who knocked at the gates of Heaven. St. Peter responded and said he was sorry but he could not let Communists in. "We know that," said one of the Russians. "We just came to see if you would give us back our ball."

For Mr. Morrow, the conference chairman, it was indeed a busy Saturday. He dined that evening in Washington, to accept a citation for his company's defense work. But the program went smoothly on at Detroit, thanks to vice-chairman Robert J. Meier, '41, and a committee consisting of Morgan A. Collins, Jr., '27; Patrick E. Colvan, '48; Robert M. Gaudin, '52; Roy C. Haeusler, '32; Charles M. Jordan, '49; W. James Mast, '53; John D. Rumsey, '33; David M. Sutter, '26; and Jervis C. Webb, '37.

(*Continued on page 252*)

Air Defense Research in the Space Age

Lincoln Laboratory is helping to assure American supremacy on a vital front by seeking more basic knowledge and planning more intelligent machines

by CARL F. J. OVERHAGE

THE fact which dominates our lives in this space age is that two great powers are competing for world leadership. In the past, such situations have often been resolved by warfare, and thus a good deal of thought is now being given to the possibility of a third and thermonuclear world war. We are determined to avoid such a war. We hope to do this by establishing a military equilibrium between the United States and its potential enemies.

Toward this end, we are steadily expanding and improving our early warning systems, so that no enemy will assume that, without danger to himself, he can annihilate us in a single massive surprise attack. We are building up our active defenses against both aircraft and missiles, so that an effective attack will become more and more costly to an enemy. And we are constantly adding to the power of our strategic weapons so that an enemy will not contemplate an attack on the United States without the certain knowledge that he is exposed to immediate counterattack.

Dr. Overhage became associated with M.I.T. during the war, helped organize Lincoln Laboratory, and is now its director.

As we gradually achieve these objectives, it is becoming apparent that the front on which the issue of world leadership is really going to be settled is that of science and technology. The peoples of the world are determined to avoid thermonuclear conflict. I believe that they will, of their own volition, align themselves with the side that establishes a clear superiority in science and technology. For it is in science and technology that the masses of Asia and Africa seek their salvation. It is in science and technology that we compete with communism for the control of the underdeveloped countries. And it is in science and technology that the Soviet Union is intent on matching and surpassing the United States.

My insistence on science and technology as the primary issue may sound a little brash. I am not deaf to the civilized voices of George Kennan and of Barbara Ward, of Paul Henri Spaak and of Walter Lippmann. Science and technology is not the only front on which we have to fight. But it is the front of which I have some firsthand knowledge, and I have become firmly convinced that if we fail on this front the Western cause will be lost.

Technical Centers

Our American resources in science and technology are substantial. In the leading position, we have our universities and their academic research institutes. Here the primary motivation is to secure the continuity and stimulate the advancement of the system of thought and knowledge which constitutes Western civilization. Next, we have our government laboratories, dedicated to research in specific directions in which Congress and the Administration seek to promote the welfare of the nation. Third, we have our industrial research laboratories, where a vigorously expanding effort is under way to provide the technological foundations for new commercial products and services. Finally, we have a fourth and new type of establishment: a group of technical centers operated under government contracts by some of our major universities.

In this last category, which has its origins in World War II, we find a concentration of effort in those new fields of science and technology that are most perti-

The Lincoln Laboratory of M.I.T., near Hanscom Field in Lexington, has four main buildings with a total area of 300,000 square feet. There are also shops and service buildings and a prototype air defense direction center (seen at the left in rear).

nent to our military needs. For example, in its laboratories at Los Alamos, at Berkeley, and at Livermore, the University of California works on the problems of nuclear weapons. The Jet Propulsion Laboratory at California Institute of Technology is concerned with rocket technology. The program of the James Forrestal Research Center of Princeton University includes research on fusion reactions. Columbia University is operating the Hudson Laboratories for investigations related to undersea warfare. And at Lincoln Laboratory, M.I.T. has organized a technical center for advanced electronics with special attention to air defense applications.

These technical centers are large enterprises. Lincoln Laboratory's size can be judged from the photograph on this page. Even so, much of our experimental work is done at field stations away from the central laboratory. These include a radar site 120 miles north of us in Maine, with a rather unusual air surveillance radar; a more recent radar of this type on a site near Andover, Mass.; and a communication research site by the ocean on a handsome estate which was given to M.I.T. by the family of its late owner, Colonel E. H. R. Green.

The Institute's Responsibility

Most of the physical facilities are the property of the United States Air Force. Lincoln Laboratory, as an operation, is staffed and managed by M.I.T. under a contract in which funds are jointly provided by Army, Navy, and Air Force, with the largest contribution coming from the Air Force. Lincoln Laboratory is thus a part of M.I.T., and we have many intellectual and administrative ties with the Institute, although we are separated by 15 miles from the campus in Cambridge.

The involvement of M.I.T. in this enterprise goes back to 1951, and the circumstances that led the Institute to engage in a large activity so far removed from its primary task of education are interesting. First of all, the appeal from the Air Force to M.I.T. came at a time when the nation was confronted with a sudden emergency as a result of the unexpected atomic explosion in the Soviet Union. The new threat of atomic attack against the continental United States, by high-speed aircraft in large numbers, called urgently for a drastic new approach to our air defense. Such an approach had already been suggested by a committee under George E. Valley, Jr., '35, Professor of Physics at M.I.T. Centralized control of the air battle over a vast area had become possible with postwar advances in high-speed computers; radar data could be automatically inserted into these computers; command instructions to interceptors and missiles could be issued by the computers with a minimum of human supervision. These ideas had grown from roots deeply embedded in the work of several M.I.T. laboratories – notably the Radiation Laboratory, the Research Laboratory of Electronics, and the Digital Computer Laboratory. The existence of these resources in experience and talent at M.I.T. made it impossible to escape the responsibility for translating the new concept from a committee report to an operating reality. The decision to accept the job was in the best tradition of an institution which, in the words of J. A. Stratton, '23, President, is characterized by a "relatedness to the world of action as well as to the world of thought."

The system which resulted from this work came to

be called SAGE (Semi-Automatic Ground Environment); we have carried its development to the point where the first two of 29 SAGE air defense sectors are in operational use. The remaining sectors are in varying states of completion, and all necessary equipment is in commercial production. The nerve center of each sector is a Direction Center, where a four-story building houses two special computers, each with more than 60,000 vacuum tubes. The nation's total capital investment in this electronic network will be well over a billion dollars.

At this stage, the big problems are in the area of system integration and system management, and these problems are outside the field in which M.I.T. as a public educational trust believes it can properly engage. Therefore M.I.T. is now taking steps, with Air Force concurrence, to separate the tasks of SAGE System engineering and management from Lincoln's continuing research and development pursuits, and to transfer the SAGE activities to a new nonprofit organization, the Mitre Corporation, which will be independent of M.I.T.

On Millstone Hill in Westford, 30 miles northwest of Boston, Lincoln Laboratory has this large radar research installation. Its 84-foot reflector is mounted 90 feet above the ground.

Defense against Ballistic Missiles

Turning now to the space age, what new problems do we encounter in air defense? First of all, what exactly do we mean by the "space age"?

As we leave the surface of the earth, the density of the air decreases, and at an altitude of 20 miles or roughly 100,000 feet we are on top of 98 per cent of the total air that surrounds our planet. Above this level, the air is too thin to support normal aircraft or balloons. To penetrate this higher region, we need vehicles propelled by rockets. Such vehicles have become practical during the last 15 years. They have not yet been used to transport human observers, but this is rather imminent, and meanwhile a good deal has been learned from instrumented missiles.

A space vehicle is propelled by its rocket engines for only a brief period at the beginning of its journey. During this interval it rises beyond the atmosphere and acquires a very high velocity. It is then separated from its power plant and continues on its journey without external constraints other than gravity. Its initial velocity may be adjusted so that its trajectory is relatively short; in that case, the vehicle re-enters the atmosphere a few hundred or a few thousand miles away from its launching point, and we speak of a ballistic missile. If the velocity is raised to about 18,000 miles per hour, the vehicle can be directed into an elliptical orbit entirely outside the earth and its atmosphere. We then speak of a satellite, and, if the lowest point of its orbit is high enough to make the atmospheric drag negligible, the satellite vehicle will keep circling the earth for many months or even years. A third type of space vehicle, with a still higher initial velocity, is designed to escape from the earth altogether and to be drawn into an orbit around the moon, or one of the nearer planets. These are the space

In the Millstone Hill control room, radar reflections from the aurora and space vehicles have often been recorded.

Several times, vehicles launched from Cape Canaveral have been seen and information obtained about their trajectories.

probes, with which the Army and the Air Force are currently experimenting.

Our specific interest at Lincoln Laboratory is in the detection and tracking of these objects. They are generally invisible, and we must depend on radio and radar techniques to sense the presence of these vehicles in space.

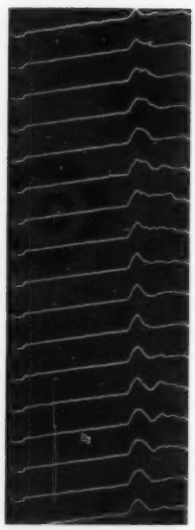
In air defense, we must be prepared to deal with missiles that are unwilling to cooperate with us by emitting suitable radio signals, and we are therefore concentrating our attention on radar observations in which we transmit our own signal and listen to the echo reflected by the object in space. This technique, which has been so successfully used for aircraft detection, will also work for ballistic missiles, but we shall have to cope with some quite substantial new difficulties. The objects are very much smaller than aircraft; they travel at very high speeds; and if proper warning is to be given of their approach, they have to be detected very far away. Therefore our radars must be very large and powerful, and our technology in this field must be stretched well beyond its present limits. Then, too, we find that radar signal transmission at these great altitudes and ranges is affected by the aurora, by meteors, and by polarization effects in the ionosphere. A lot of experimental research will have to be done before we can competently deal with these matters.

Our Millstone Hill Observatory, shown on page 241, was specifically designed for the study of this type of radar problem. The observatory site is dominated by an antenna with an 84-foot parabolic reflector mounted 90 feet above the ground. This antenna can be pointed toward any direction in the sky, and it can be moved with sufficient speed to follow a rapidly moving object. The antenna is fed from a high-power transmitter in the building at the left. The same buildings contain receiving and computing equipment in which the reflected signals are automatically processed to yield immediate data on the orbits of the observed objects.

Some records of actual signals observed with this radar are shown on this page. The group at the top consists of reflections from an aurora, the group in the center shows reflections from the moon, and the one at the bottom shows the echo from the satellite 1957 Alpha – the first of the Sputniks – as it passed through the radar beam. You will note the interesting differences. Broad patterns are characteristic of extended reflectors, and a sharp echo is returned from a much smaller satellite object.

While we have pursued our investigations with this research radar, the Air Force and

Aurora



Moon

Satellite

Patterns of radar signals reflected from the aurora and moon (at right above) are broad compared to the sharp returns from a much smaller satellite.

Army have been launching assorted space vehicles from the Missile Test Center about 1,000 miles away at Cape Canaveral, Fla. After they have attained sufficient altitude, these vehicles can be seen with the Millstone Hill radar, and we have on several occasions interrupted the scientific program at our observatory in order to provide operating information on vehicle trajectories. The sense of participation in these space launchings has been a thrilling experience to the Lincoln Laboratory, but what has been even more rewarding is the use of Lincoln Laboratory designs for the radar detection and tracking equipment that will be used in the arctic stations of the Air Force Ballistic Missile Early Warning System.

Active Defense

So far, I have talked of the detection and tracking of space vehicles, and I have implied that the orbit of the vehicle can be determined from radar data. If the vehicle is a ballistic missile rather than a satellite, the orbit will define its probable point of impact and point of origin. I need not point out the air defense implications of such data. But having detected a missile and identified its orbit as hostile is not enough. We are still faced with the problem of intercepting and destroying it. This is the so-called active phase of air defense. Here the electronics engineer shares the stage with the missile designer and the nuclear weapons specialist, and the security people see to it that the whole performance takes place behind a closed curtain.

I can only suggest the nature of some of the difficulties that must be overcome. The hostile ballistic missile that carries an atomic warhead may be accompanied by so-called decoys, light and inexpensive objects which travel through space on the same orbit, and which the radar cannot easily distinguish from the real article. The enemy may also attempt to confuse our radars by signals from jamming transmitters. He may try to saturate our defenses by launching several closely spaced small warheads instead of a single large one. In working toward solutions of these problems, we are badly handicapped by not knowing nearly enough about the physical phenomena associated with the reentry of a space vehicle into the atmosphere. We are trying to acquire this knowledge by making observations at the far end of our own test ranges, but this is a slow and expensive program. To the greatest possible extent we must therefore seek to explore these phenomena in laboratory experiments.

It is characteristic of technical centers like Lincoln that they operate under a very broad interpretation of their task. In addition to the projects aimed at specific new weapons, one will always find development

programs in the fields of component technology. And most important of all, one will find substantial efforts to advance the underlying scientific understanding in these fields, even if the military applications are not immediately apparent.

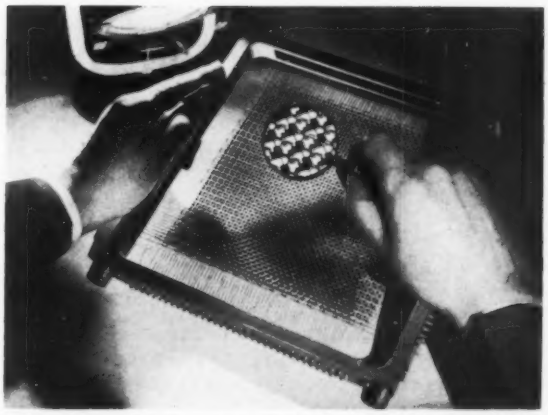
Solid State Research

Solid state physics is one of the broad areas in which we are seeking at Lincoln Laboratory to advance our general scientific insight. This is a very young science. It was only after the development of quantum mechanics in the period between World Wars I and II the physicists began to grasp the nature of the solid state.

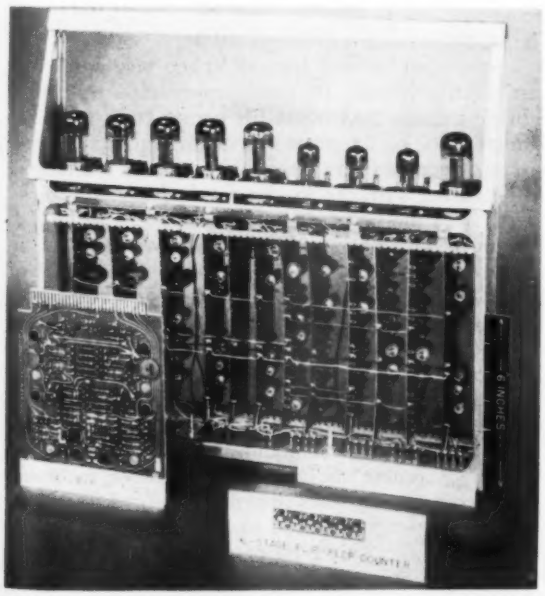
Late in the forties, the transistor was invented at Bell Telephone Laboratories. The impact of this discovery on computer technology is suggested by a photograph on this page. It shows three subassemblies that are roughly comparable in function. The largest is representative of the 1950 technology utilized in the SAGE computer. The intermediate circuit is typical of the 1955 generation of circuits in which transistors have replaced vacuum tubes. This type of assembly is utilized in our computer at Millstone Hill. The smallest circuit was built in 1958.

In the design of computers, an equally important application of solid state physics was the ferrite memory core. M.I.T. has played a pioneering role in the development of this device which has been utilized in the high-speed memories of most of the modern computers. These cores are about 80 thousandths of an inch in diameter. They are wired in memory planes, each one of which contains 65,000 of these ferrite cores. There are 37 such planes in the memory of Lincoln's TX-2 computer.

With these two developments in mind, you will understand our faith in the value of further solid state studies. Under the leadership of Benjamin Lax, '49, one of the country's outstanding solid state teams has been built up at Lincoln Laboratory. The pages in the scientific journals which contain the achievements of that group are, in my view, as important a contribution to national security as the radars of which I spoke earlier.



Memory cores like these in the TX-2 computer hold 2,500,000 bits of information. Recall time is six microseconds.



The 1958 computer subassembly in foreground is functionally comparable to 1955 unit at left and 1950 unit in rear.

Man-Machine Communication

Another research area in which we believe the potential rewards are very large is the field of intercommunication between men and machines. We have been led into this field primarily by our work with computers. Compared with the high sophistication of the internal works of these machines, we have long felt at Lincoln Laboratory that their input and output devices are rather pedestrian affairs. Our TX-2 computer can multiply 10-digit numbers with each other in 15 millionths of a second. But when it comes to accepting instructions, the computer likes to have the operator punch a keyboard. At most it will take electrical pulses stored on a magnetic tape. Why should it not learn to understand plain English? And what is so insuperably difficult about reading a printed page? These are accomplishments that the more intelligent machines of the future will surely have, and we are working toward this goal by projects in speech recognition and in pattern recognition. We do not believe that the answers are just around the corner, but the challenge is persistent.

While this survey of our work has had to be fragmentary, it will have shown that our program extends from fundamental investigations in science through technological development to the design and construction of complex weapon systems. This broad "spectrum" of activities is based on a strong conviction that enduring competence can be achieved only where these different types of work are carried on side by side, under the same roof, by a single integrated team. I believe this is more than a crotchety academic notion: I believe it is the translation into practice of the principle I tried to suggest at the beginning. We need certain weapon systems to maintain viable military balance, and we need supremacy in science and technology to maintain world leadership.

Where We Stand in Space

The uses and vehicles of space technology are numerous and challenges right now in engineering exceed those in science

by H. GUYFORD STEVER

Without doubt, the number one news story of the last year was ballistic rockets and spacecraft. When a Special Committee on Space Technology undertook to determine for the National Aeronautics and Space Administration where more effort was currently most needed, the results were surprising to many of us. A large portion of the foreseeable goals of space technology can be achieved with existing knowledge of scientific principles. The problems now are mostly in engineering.

At least four different aspects of human endeavor have a real interest in the solution of these problems. Scientific research would be one of the principal beneficiaries. Space-flight capability would ensure the performance of a number of experiments that are not possible now.

The surveillance of the earth's atmosphere from a point of vantage in space, for example, certainly can teach much about the world's weather. The sun's radiations and cosmic rays from outer space can be studied without the interference of earth's protective atmosphere. The nature of the plasma, the tenuous electrified gas, which exists between the principal bodies of the solar system, can be determined. Unusual studies can be made, too, in the biology and biochemistry of life, especially on a planet like Mars, where simple forms of life may exist, or the Moon, which biologically may be pure.

Another field of human endeavor affected by space capability, of course, is military. The importance of ballistic missiles becomes clear when one considers the range to which a large nuclear bomb can be accurately delivered, at relatively small cost, by a vehicle in which there is no risk of human life, and whose accuracy, speed, and route of approach make defense extremely difficult, if not practically impossible. Space capability also can help in military reconnaissance.

A third kind of human activity in which there is a clear interest in space capability is exploration and adventure. We look forward now to exploring the planets and their satellites in the solar system in the next few decades. Ours is the first generation to have that capability; the curiosity and sense of adventure which has long been a driving force in man will lead him to explore the solar system now that he can.

Space capability also can improve, by engineering achievement, the daily life of humans. A clearly seen example is in communications. In a very few years we will be able to establish vehicles in space which can be used as relay stations, either active or passive, for direct, line-of-sight communications between any points on the surface of the earth, thus eliminating the need for coaxial cables, either over ground or under sea, or the numerous ground-based microwave relay stations now in use.

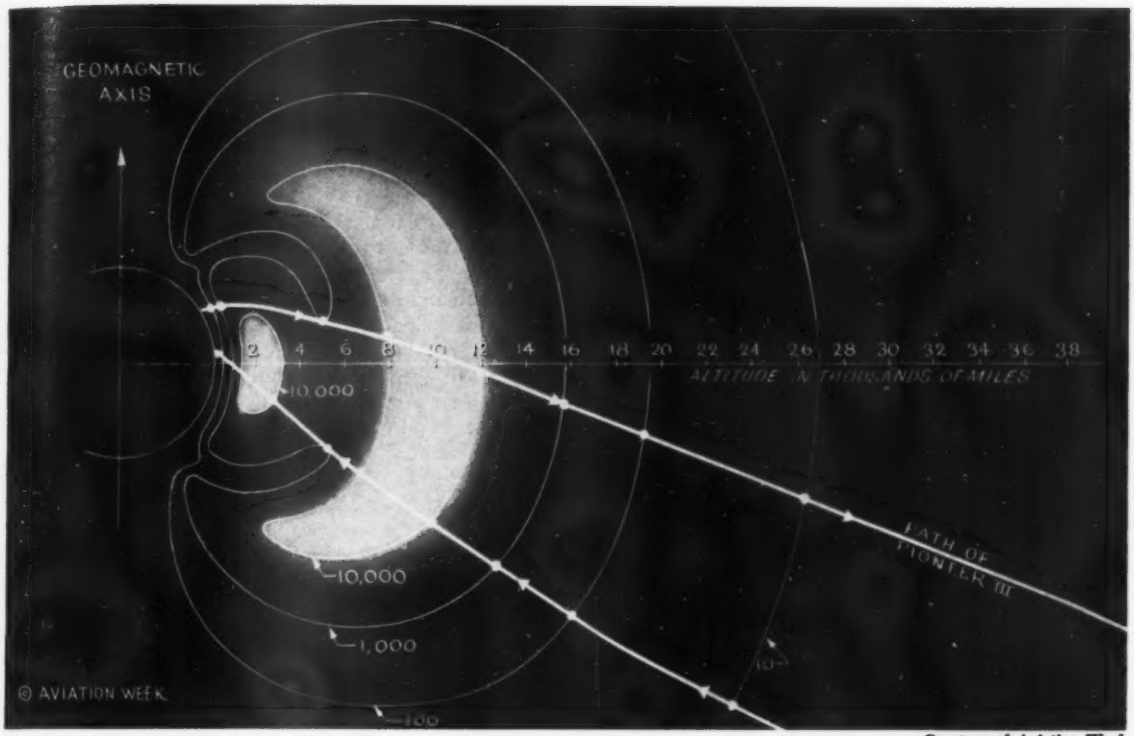
The scientific research and engineering development required to realize these objectives greatly overlap. Many categories and classes of space vehicles can be used for these four different purposes. A long-range ballistic missile can be designed to carry a nuclear warhead a substantial fraction of the distance around the globe with sufficient accuracy to make it a worth-while military weapon. The same vehicle, with the military warhead replaced by scientific equipment, can be used as a scientific probe into the upper atmosphere.

A Variety of Vehicles

A whole spectrum of space vehicles can be conceived between the ballistic missile and the earth satellite. Many of these conceptions are now receiving active study or development. One such device is the boost-glide vehicle which can be used either to explore the technical nature of the upper atmosphere, or as a military weapon to carry a nuclear warhead or reconnaissance apparatus. Such a vehicle is the X-15 which will fly soon. It is designed to be boosted approximately 100 miles in altitude by a rocket engine at speeds up to 3,600 miles per hour. Having reached its high altitude, it will use aerodynamic lifting surfaces to glide at high speed back to earth. The resulting range will be quite large.

A somewhat related type of space vehicle is the semiballistic vehicle. Its speed approaches that of a ballistic missile. Part of its lift comes from the centrifugal force of its curved path through space and part of it comes from aerodynamic forces generated by its lifting surfaces in the rarefied upper atmosphere. Both the boost-glide and the semiballistic vehicle have been proposed as military weapons.

There is yet another "in-between" type vehicle, known as the satelloid or semisatellite, whose path circles the earth just like that of a true satellite. The satelloid, however, is at an altitude somewhat lower than normal satellite altitude, say at 90 miles, where it tends to lose its energy quite quickly because of the drag of the atmosphere. It would naturally spiral back to earth. The satelloid, however, employs a very small rocket motor applying thrust in small bursts from time to time, in order to refurnish it with the kinetic energy required to remain at this "in-between" altitude. This type of vehicle has been proposed for military reconnaissance. Its advantage is that its path is lower and, consequently, optical or other detection means are kept closer to the ground.

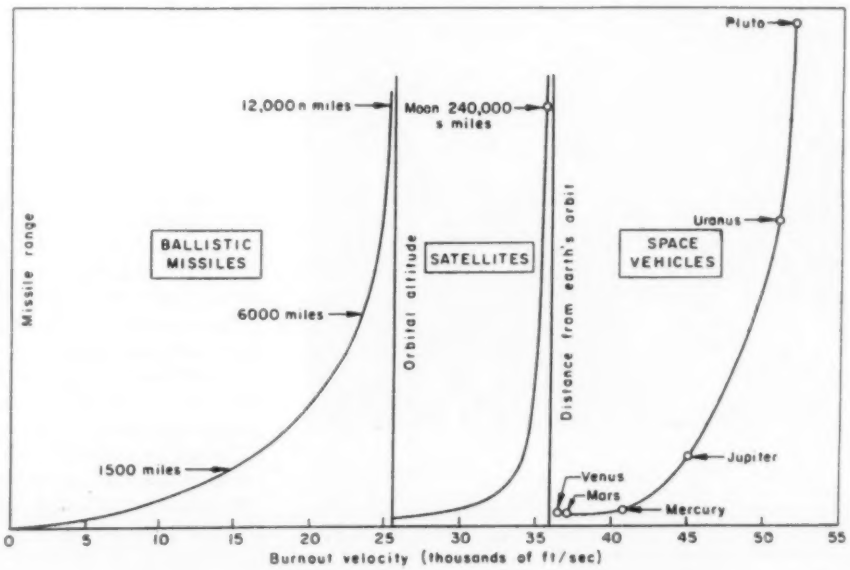

GEOMAGNETIC AXIS
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38
ALTITUDE IN THOUSANDS OF MILES
10,000
10,000
1,000
100
PATH OF PIONEER III
© AVIATION WEEK

Courtesy of Aviation Week

This is an intensity profile of the "Van Allen" radiation around the earth. Two belts of intense radiation have been found at the altitudes indicated from left to right. Number of counts per second registered by Geiger counters in Army Pioneer III space probe is also shown. Relatively low-intensity "horns" which project outward at higher geomagnetic latitudes may result from atmospheric heating, produced by radiation that leaks in along converging magnetic lines of force, which pushes radiation outward. Peak radiation measured is about 10 roentgens per hour, if it consists of electrons; 100, if protons. Minimum radiation at 6,000 miles is .3 roentgens if electrons, 3 if protons.

Still another type of space vehicle is the satellite of the sun. The successful Russian rocket called the Dream has shown us that this is an interesting mission. One can conceive of vehicles of the same sort, although larger and probably more complicated, becoming satellites of other planets.

Another series of space vehicles of the future will be those which can land on another planet and then, going one step beyond that, those which can both land on and take off from a planet. Finally, in the distant future, there will be true spacecraft which have all the freedom to move wherever mastered by their



This graph shows the velocity requirements at the final burnout time for a number of space missions of current and future interest. It is interesting to note that only a small velocity difference exists between the requirements for extreme-range ballistic missiles and low-altitude satellites, and between those for very high-altitude satellites and Venus and Mars probes.

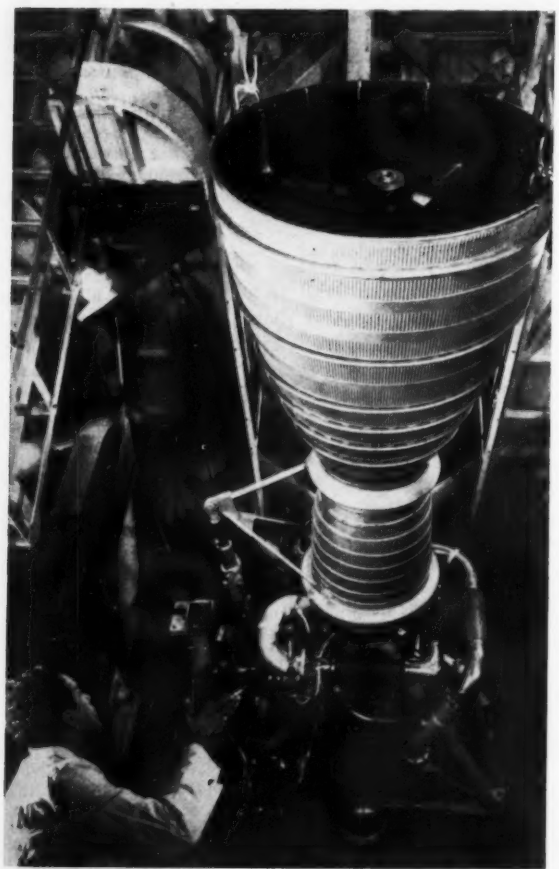
occupants or controllers on earth. This type of spacecraft, with freedom to navigate about the solar system, is far beyond our present capabilities, but it is one of our dreams.

With four major fields of human endeavor involved in the space effort and about 10 different major types of vehicles, it is clear that the engineering problems are legion.

Propulsion

Propulsion is the key technical field of space flight. Today nearly all our activities are based on large liquid-propellant rocket motors. The solid-propellant rocket motor does not have as high performance potential as the liquid propellant, although its simplicity and reliability have won it a certain place, especially in the upper, smaller stages of space vehicles.

In general, two major characteristics in the performance of a rocket motor determine its quality. One is the specific impulse which determines the amount of propellant that must be burned per unit of time to produce a given force, or thrust. The second is the dead weight of the engine itself, including the tanks, power supplies, and structure involved. The chemical rockets have achieved in design and practice a reasonably light weight per unit of thrust, but the specific impulse is not too good. Two hundred-fifty pounds thrust per pound per second of fuel burned is a typical characteristic of current rocket engines. Liquid-propellant rockets of the future may have specific impulses of 300 to 350, and solid propellants may run as high as 300.



Allegheny Ludlum Steel Corporation

The thrust chamber of the U.S. Army Jupiter intermediate-range ballistic missile is shown here. Massive ducts which carry liquid oxygen from pump to chamber have flex joints. Temperature changes encountered range from —297 degrees Fahrenheit to several hundred degrees above.

Because of this relatively low specific impulse of the chemical rocket, compared with the specific impulse of nuclear rockets and more glamorous types of reaction motors, immediate proposals to proceed in research and development of the more advanced type have been made. In the Congressional discussions a year ago which preceded the establishment of the National Aeronautics and Space Administration, there were serious proposals to give the entire space mission to the Atomic Energy Commission because of exaggerated claims that the entire future of space travel depended upon nuclear rockets. But, fortunately, this was not done.

We have immense capability with rocket vehicles either already developed or in advanced stages of development. The Atlas and the Titan could be designed to carry 500 to 2,500 pounds to a 22,400-mile stationary satellite orbit. Such a satellite would hover over a point on the earth because its period of revolution would be 24 hours, corresponding to the daily rotation of the earth. These intercontinental ballistic missiles could also provide a moon impact of 600 to 3,000 pounds, establish a moon satellite of 300 to 1,500 pounds, establish a moon landing of 200 to 1,000 pounds, or go to the region of Venus and Mars with 500 to 2,500 pounds, or to the region of Jupiter with 300 to 1,500 pounds.

Under development currently are rocket engines in the million-pound thrust category. Presumably several years will elapse before these are available. Two approaches are being taken, one in which a number of smaller units are grouped together, and another in which a single-barrel rocket motor of a million-pound thrust is being developed. Rocket vehicles based on such rocket motors can put 25,000 to 50,000 pounds of pay-load weight into a 300-mile satellite orbit.

Even though these space missions would be quite impressive, we would like now to develop some of the technological devices which will be needed in our space program 10 or 15 years from now. In the propulsion field, several offer promise. A rocket using a liquid working fluid, say hydrogen or ammonia, and a nuclear reactor as a heat source offers promise of specific impulses considerably higher than the liquid-propellant rockets employing chemical energy, say in the range of 400 to 1,200 pounds thrust per pound per second of fluid expelled. These nuclear rockets are under development at the present time.

Three types of rockets of still more advanced form have been suggested for use in outer space where a small thrust is required over a very long period of time, such as might be the case in a true space ship as it maneuvers from an earthly satellite orbit out to a distant planet and back. One is the ion engine, in which an ionized metallic substance such as cesium is accelerated in an electric field. This is quite similar to the way charged particles are accelerated in the large

(*Continued on page 258*)

Bradford Washburn

Of 20,000 potential freshmen, 7,000 make inquiry about M.I.T. from the Admissions Office, 4,000 submit final application, 1,800 complete admission requirements, and 900 actually register at the Institute.

The Problems of College Admissions—II

Of the many unsolved problems in selecting students for higher education, those related to emotional factors leading to poor motivation are among the most difficult

by B. ALDEN THRESHER

With potential college enrollment growing more rapidly than educational facilities, the problem of college admissions is troublesome to many students and their parents, as well as to institutions of higher learning. Professor Thresher's timely survey of today's admissions problems of college students is based on a quarter of a century of first-hand dealing with such problems. In the February issue, Professor Thresher discussed college admissions in general as a complex operation involving students, parents, counseling personnel, and various examining bodies. This month, the emphasis is on factors more directly associated with admissions to M.I.T. — Ed.

EACH year the M.I.T. Admissions Office is in contact with something like 20,000 potential freshmen. This is the number of high school students who either write us a letter, come in to see us, or who talk with an Institute representative in one of our high school visits or with an Educational Counselor in some local area. These 20,000 represent the immediate potential market for freshman admission in the sense that all of these young people have had an opportunity to look at M.I.T. literature, to talk with somebody about the Institute, and to give active consideration to the possibility of whether or not they can or will attend. Out of this number something like 7,000 actually fill out a preliminary application, a costless and simple formality.

To all of these are sent, in turn, the necessary complete final application papers, and about 4,000 submit final applications in detail, take the necessary tests given by the College Entrance Examination Board, and pay a $10 fee. Our actual selection, therefore, concerns this 4,000 and from them we pick approximately 1,800 to whom we send offers of admission, almost all of these offers going out about the first of May. Of these, in turn, approximately 900 actually turn up and register in September. The attrition of about 50 per cent is due to the fact that all of them apply at several institutions (actually to an average of 3.6 institutions each). Their final choice follows a process of comparison and decision which is often prolonged into the spring months, and de-

M.I.T. Photo

Each year counselors from preparatory schools around the country come to the Institute for a day or two. In addition to meetings in the Kresge Auditorium (shown above), they have opportunities to speak with former students.

pends very largely on considerations or relative cost, distance, and offers of financial aid.

The process of selecting an entering class at M.I.T. is, for the most part, concentrated in the months from January to May. We normally have, for each applicant, in addition to the usual kinds of data which he himself provides on a six-page application form, personal endorsements written by two teachers who know him well and whom he himself selects. These are sent to us directly without going through the student's hands. We also have a special report form from each secondary school which he has attended, including not only his marks and his rank in class, but the answers to questions about his merits as a school citizen, as a student, and as a person. There is also normally a memorandum made following an interview, either with a member of the Educational Council in some distant center, or here in Cambridge if a student has been able to visit us — or sometimes both. All of this material is held in strict confidence, so that school officials will feel free to speak frankly about applicants.

Upon initial contact with the Institute, freshmen are likely to find M.I.T. a large and labyrinthine group of buildings. The map (shown below), adjacent to the Information Office in the lobby of the Rogers Building, is often consulted.

George W. Brown, '56

It is very important that, as the pressure of applications enables us to be more and more selective, this selectivity should not work itself out solely in terms of test scores or school marks. While we do want students who have high intellectual promise, we know perfectly well that the ultimate peak of high marks is by no means the only consideration. We therefore feel that, as selectivity increases, the broad personal estimate of each applicant should be given an increasing relative weight. Even after we have done this, we find that we are still getting on the average a group which each year shows a higher average performance in high school and on their test scores. While we can safely predict that the Alumni who will do us most credit in future years will be, in the main, those with high intellectual ability, they will not necessarily be those at the very apex of high marks. We feel that the considered judgment of school principals, teachers, and counselors who are adept at judging young people should be given a great deal of weight in predicting probable performance.

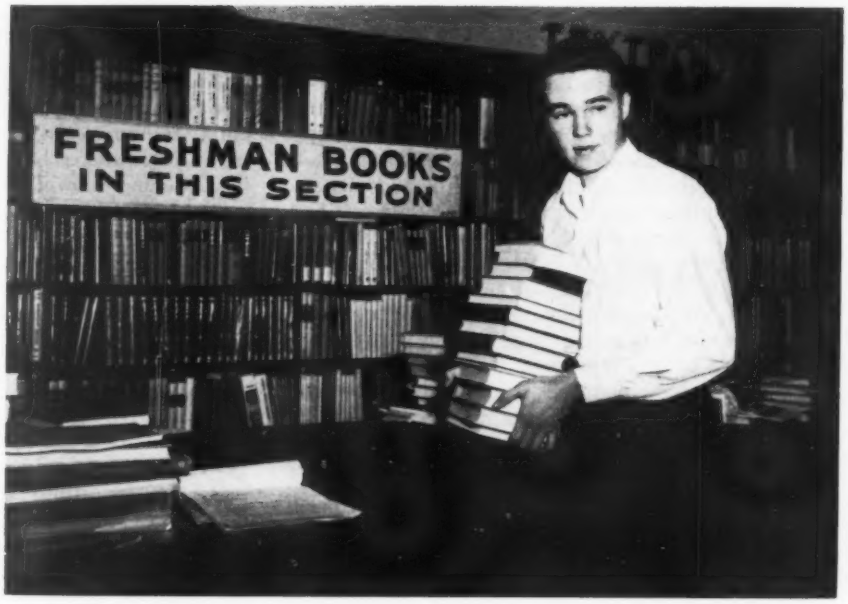
The selection of an entering class involves the appraisal of human excellence in many aspects. Whether a student is admitted depends on an estimate of future behavior and performance, a process necessarily subject to many errors and miscalculations. No one factor, or set of factors, can decide this question, and test scores and statistical devices are only partially effective in giving an answer. Such quantitative data are therefore always subordinate to the indispensable element of personal judgment upon which all decisions about admission must finally depend.

Competition and Comparison

As soon as each candidate's folder becomes complete, it is carefully read and evaluated with reference to the candidate's personal promise based on all the evidence we are able to assemble. In April when scores become available from the March College Board tests, a statistical index is computed, including not only test scores but also school marks and rank in the high school class. This index is retained as a measurement separate from the personal evaluation made earlier. The two are kept separate until the final stage of selection so that we can, for example, see how much we are giving up in academic ability to secure a student of exceptional qualities of leadership, energy, or breadth. Doubtful or borderline cases are read and discussed by several members of the admissions staff.

No question is asked us more frequently by Alumni and by schools than, "Why was this boy refused?" The normal assumption, when this question is asked, is that there is some flaw or defect in the student's record which has disqualified him, and the next step is to ask whether this flaw or defect can in some way be remedied so that he can in turn qualify. It is important, however, to bear in mind that in a system of selective admission the process is not as simple as this. It is not simply a matter of meeting certain fixed requirements and thereby qualifying. Our problem is rather to select a limited number, which is all we can accommodate, and this makes the whole process a competitive and comparative one.

Purchase of textbooks is not a part of the problem of gaining admission to college. But once the admissions problems are solved, the successful candidates quickly become customers of the Harvard Co-operative Society (better known as "The Coop") where texts in physics, chemistry, mathematics, and the humanities outline much of their first year's work at M.I.T.



M.I.T. Photo

We can make no pretense of superior wisdom in our selection process. The one great advantage we have, however, is the opportunity to intercompare all the candidates simultaneously. This cannot be done by the people who write in, often indignantly, about the refusal of a particular candidate. If we refuse a student, therefore, it is not necessarily because there is any flaw in his record or personality, but simply because we have others who, on the whole, and in our best judgment, seem better qualified and who show even greater promise. The queries as to why a candidate was rejected can therefore be answered best by this general principle.

The gradual improvement of our selective processes over a period of years has had a number of interesting results. The most obvious test of the effectiveness of a prediction system in connection with admissions is the degree of correlation between the prediction of performance on the one hand and actual performance of students on the other. What is often not realized is that as selectivity becomes greater, and as we take only a small fraction of students from very near the top of the distribution, this correlation actually decreases. If we were to accept all applicants there would be a very high degree of correlation between predicted performance and actual performance. There would also be a large number of failures. As we confine our admissions to a group very high in the total distribution, random elements play a relatively greater part in the variation so that, in general, the stronger the class the less the correlation with predicted performance.

One might suppose also that as the intellectual abilities of the entering classes become successively better in successive years, as has now been demonstrably the case for some time, we could detect a higher average level of marks, say, in the freshman courses. This, however, seems to be a vain hope. There is no such thing as an absolute standard of undergraduate performance, and the Faculty, perhaps unconsciously, but yet inevitably, tends to push a class about as hard as it can be pushed. Thus it is very difficult to increase to any great extent the level of grades in individual freshman subjects by improving the quality of the class. Despite this fact it has been possible in the last 20 years, through careful selective processes, to raise the proportion of M.I.T. students who complete the course and graduate from below 60 per cent to about 71 per cent.

People often ask us why we are not able to identify, in advance, a larger number of students who are likely to fail, and to eliminate them from consideration at an early stage. Actually, this is a much more difficult task than appears on the surface. None of these decisions is absolute but represent rather probabilities of future performance. It would indeed be possible to increase somewhat the probability of academic success if we were sufficiently tough in the selective process. This in turn, however, would result in our excluding a great many students who actually would have done well had they entered. To exclude all those who might fail could never be done completely, and if we press too hard in this direction we succeed only at the cost of excluding a great many who would actually do very well. In other words, the selective process represents a statistical estimate. We are dealing always in risks and probabilities, and no candidate is ever a "sure thing." Conversely, none, however unpromising, is completely devoid of hope; some who looked quite undistinguished at entrance, have performed brilliantly.

Danger Signs in Admission

Admissions officers come to recognize characteristic danger signs in applicants. Perhaps the most serious of these dangers is the ambitious parent. Let me hasten to explain, however, what kinds of ambition in parents are dangerous. The parent who wishes his son or daughter to mature gradually into a self-reliant adult who has realized his or her potentialities, is ambitious in the right way. One can have no quarrel

with parental ambition of this kind. The danger lies in the parent who has made an arbitrary choice of what he wants the student to do, or sets arbitrary goals which may have no reference whatever to the student's potentialities or interests. Every admissions officer sees instances of parents who are working out their own frustrated ambitions in terms of goals set for their children. One learns to sense also situations in which the boy or girl is being forced into an educational program thought by the parent to be desirable, but which may be quite unsuited to the youngster's abilities or inclinations. There is no surer prescription for failure in college than excessive pressure exerted by a parent toward a goal which, from the student's point of view, may be arbitrary or inappropriate, even though the parent may think it an admirable one. Often, too, a parent who indignantly denies exerting any pressure on the child can be found to do so, perhaps unconsciously.

A special case of this situation is the choice of college on a purely conventional basis. The mother may decide that her daughter's social standing requires her to enter a particular college, or the choice of a college for a boy may be dictated by a mistaken idea that its "prestige" will somehow rub off on him, thus conferring upon him permanent advantage or a head start for the rest of his life. Probably the best advice that can be given to most such parents is to relax and let their children proceed at their own pace and in their own way with only a minimum amount of guidance and advice.

There is also the tense, overcompetitive parent who manages to convey this same feeling of tension to the child, and so to destroy the normal joy in learning that a youngster of good intelligence will feel if he is let alone and allowed to proceed at his own pace.

Another danger sign appears in situations where the parent is clearly taking all the initiative and doing all the planning. The admissions officer who glances through a folder and sees a considerable interchange of correspondence with a father or mother and no sign of any communication from the son or daughter is immediately on his guard. The well-advised parent will do everything possible to encourage the child to take initiative and stand on his own feet.

Parents often ask at what stage one should begin getting a student ready to enter college. The answer, of course, is at approximately the age of one year. The parent who brings up the child as a well-adjusted, healthy individual who is interested in the world around him, has had his innate curiosity encouraged and wants to learn, is taking the most important step toward this end. A child brought up in this way is much more likely, by the time he reaches 16, to begin to take the initiative quite naturally in looking around and investigating the possibilities open to him for higher education. He does not have to be "entered" in a college; he enters himself.

The students shown below are already well into the work of the term. The careful selection process now begins to pay dividends, for relatively few of them will fail in their studies. Most students who drop out do not lack intellectual ability or adequate preparation; their trouble stems rather from emotional problems which result in poor motivation.

M.I.T. Photo

Letters of Recommendation

A somewhat related signal of danger is the "heavy build-up." When an admissions officer begins getting letters of recommendation from United States Senators, prominent statesmen, captains of industry, and the like, particularly about a boy who has not as yet communicated with the college at all, he begins to wonder what is wrong. There is an old saying in admissions circles, "The thicker the folder the thicker the student." The ablest of students come in with a minimum of fuss. Such recommendations as they have are likely to come from people who know them well and can speak well of them. One father telephoned a few years ago to ask whether a letter of recommendation from the President of the United States would help in his son's application. It turned out upon inquiry the President did not know the boy. Obviously, then, it would be far better to have a letter from his mathematics teacher or even his basketball coach, if these really knew the boy and could speak intelligently of his performance.

It is often a sign of deep-seated trouble when the parent comes in with criticisms about the school that the boy is attending, or about the boy's teachers. The student who is a good risk for college seldom seems to get into difficulties of this kind. Where there has been friction between the parent and the school it often reflects poor performance which may be due to any one of a number of causes, not least among these being the attitude of the parent himself or the undue pressure which he may place upon the child.

Since it is the responsibility of an admissions officer to make the most careful possible selection of the

(Continued on page 266)

BUSINESS IN MOTION

To our Colleagues in American Business . . .

The initials T.A. stand for Technical Advisor. This is not a fancy title for the Revere representatives who call on prospects and customers, but rather one that designates the man having that title as being thoroughly schooled and qualified to aid manufacturers in the proper selection of non-ferrous metals.

To be a Revere Technical Advisor a man must be completely conversant with metallurgy and its application to present-day production. And, if you ask him the type of question that cannot be answered on the spot then he is qualified to present the problem to Revere's Research Laboratories in a manner that will result in a satisfactory answer.

To show you how Revere's Technical Advisory Service can render you valuable aid we cite the following example: Years ago the country's oldest manufacturer of milk coolers came to Revere with the idea of building copper-lined coolers to supplant their galvanized ones which had produced corrosion and other problems.

Revere's Technical Advisory Service worked with them in the designing of a satisfactory product. It took time, plenty of time, and experimentation. But the result was well worth the effort . . . a deoxidized Revere copper for the lining and Revere Copper Tube for the heat exchangers. But Revere's service did not stop there. For in order to keep down costs the manufacturer called on Revere's Technical Advisory Service, from time to time, to help them redesign their cooler for greater efficiency and economy. Revere Research also showed this manufacturer how to overcome their soldering and welding problems.

Because of the continuing efforts of Revere's Technical Advisory Service, in connection with Revere's Research Laboratories, this manufacturer is today in the position of being able to offer a most efficient cooler at the least possible cost. Claims of this manufacturer for this cooler are that it will cool milk, uniformly from top to bottom without mechanical refrigeration and electricity. That the cream on top will never warm up. That the cooler produces continuous 24-hour cream line cooling which removes the heat from the cream line on the top as well as from the milk on the bottom. That temperature of the milk always goes down, never up, between milkings...not one B.T.U. of heat that passes through the side walls or the bottom ever reaches the milk. This is still another example of how Revere's Technical Advisory Service was able to fit the metal to the job in order to produce a superior product at the least possible cost.

Practically every industry you can name is able to cite similar instances. So we suggest that no matter what your suppliers ship you, it would be a good idea to take them into your confidence and see if you cannot make a better product at lower costs by specifying exactly the *right* materials.

REVERE COPPER AND BRASS INCORPORATED
Founded by Paul Revere in 1801
Executive Offices: 230 Park Avenue, New York 17, N. Y.

TREND OF AFFAIRS

(*Continued from page 238*)

Of Many Interests

■ Always providing a stimulating program, the meeting of the Alumni Council on January 12 was unusual in the variety of subjects discussed. John J. Wilson, '29, President of the Alumni Association, presided at the dinner at the Faculty Club which was attended by 149 members and guests.

Donald P. Severance, '38, Secretary-Treasurer, reported changes of class affiliation for three Alumni, and that between December 4, 1958, and January 10, 1959, visits to eight M.I.T. clubs (including those of Monterrey, Guatemala, and Panama) had been made by six different members of the M.I.T. staff and officers of the Alumni Association. Also announced was the personnel of the committee for the Alumni Officers' Conference to be held next September, for which F. Leroy Foster, '25, was designated chairman.

Speaking for the Alumni Fund, Edwin D. Ryer, '20, announced that 8,533 Alumni had given a total of $344,000 to the Fund as of January 9. This is an increase of 12 per cent in number of givers and 46 per cent in amount given over corresponding figures of a year ago.

Mr. Wilson next presented J. A. Stratton, '23, whose election as President of M.I.T. had been announced and become effective since the last meeting of the Council. The warmth of Dr. Stratton's remarks was matched by the Council's welcome to him.

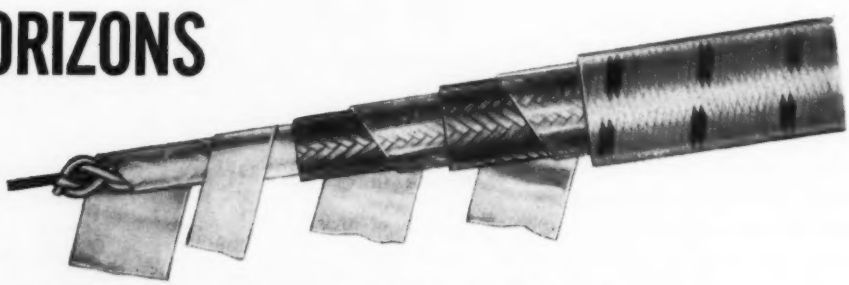
A year ago, the Institute established a new position of Planning Officer, to which Malcolm D. Rivkin, '56, was appointed. In this post, Mr. Rivkin has been assigned the task of advising the Institute's Administration on long-range planning concerning the future physical development of the Institute. He has been asked to relate the academic, research, and administrative needs of the Institute to the development of Cambridge as a whole. In particular, the dense urban character of M.I.T.'s surroundings may have major effects on the character and kind of facilities which the Institute will need in the future. Developments within the city, such as highway construction, urban renewal, and citizen action become of increasing interest.

Mr. Rivkin cited the type of growth of M.I.T. which has accentuated the Institute's need to plan ahead; that is, the volume of government research, the large number of married students, the change to a residential university environment, and the growth which, since 1940, has resulted in twice the number of undergraduate students, three times the number of graduate students, and 110 per cent more Faculty members. Speaking on problems related to automobiles, he compared the cost of a multiple-storied building (for car parking) to the cost of land acquisition in the Cambridge area for possible future use as car-parking lots; presented figures on the traffic flow on Massachusetts Avenue, Memorial Drive, Main

(*Continued on page 254*)

NEW HORIZONS

IN
LOW CAPACITY
EXTRA FLEXIBLE
COAXIAL CABLES



FOR LOW LEVEL SIGNAL CIRCUITS

These cables are particularly valuable in applications where the impulse is extremely small and where exceptional flexibility is a must. In connection with delicate brain surgery the New England Medical Research Center is presently using one of these coaxial cables. Balantine Laboratories have found that BIW 411 with a capacitance of only 10 mmf per foot is ideal for their VTVM R.F. probes.

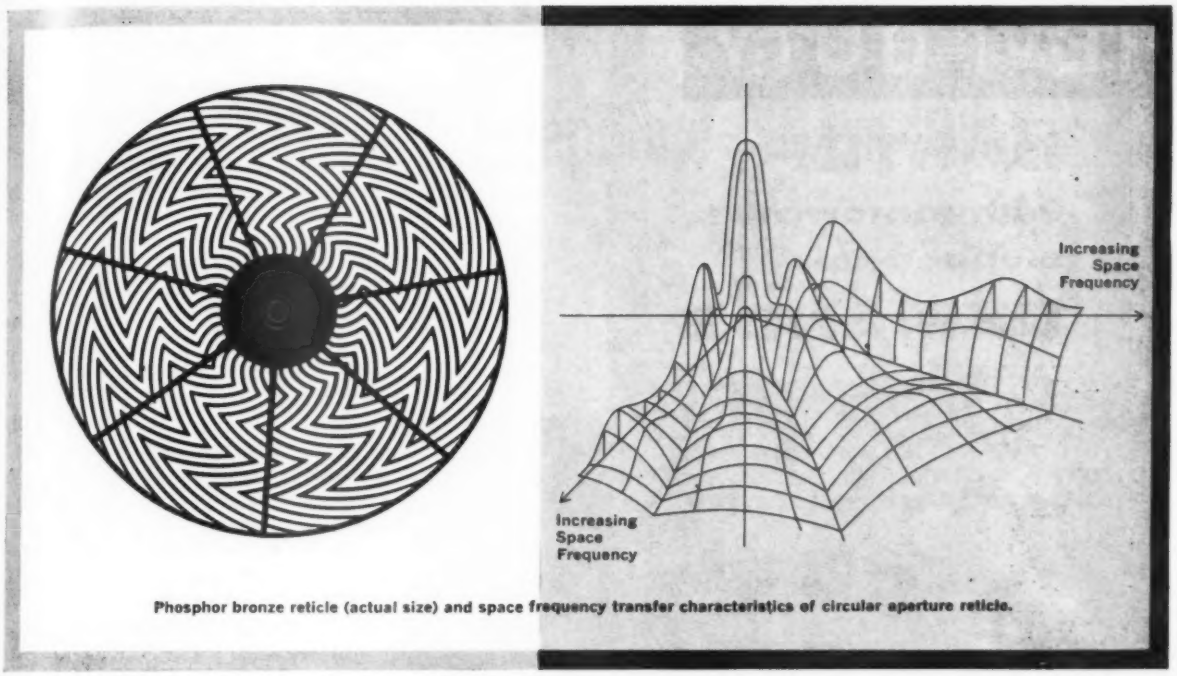
Shown above is a typical "F.F." flexi-filamented semi solid type. The insulation uses a filamented construction which imparts a large percentage of air in the cross-section. This cable, BIW COX-4FF-26-DL has a nominal capacitance of 13 mmf per foot and an OD of .175". The coaxial is very stable electrically even after flexing and vibration and it has a temperature range of −76° F to +500° F. It is used on a Firing Control System.

Other interesting cables are used for sensing circuits in missile nose cones, missile applications and high temperature aircraft — these being COX-3FF-24, COX-4FF-MG and COX-4FF-023-GF. Accepted as standard approved construction for military use is COX-4FF-026-GV RG-210/U.

Capacitance ranges from 7 mmf to 15 mmf per foot.

If your present or planned application calls for low capacity, extra flexible coaxial cables — for low level signal circuits, let us send information.

BOSTON INSULATED WIRE AND CABLE CO., BOSTON 25, MASS.



Phosphor bronze reticle (actual size) and space frequency transfer characteristics of circular aperture reticle.

TARGET DISCRIMINATION IN INFRARED DETECTION SYSTEMS

The pioneering field of infrared detection offers many challenging opportunities to scientists and engineers at Ramo-Wooldridge for advanced studies in the solution of target discrimination problems. Research is continually under way at Ramo-Wooldridge in the integrating of infrared detection devices with the latest electronic systems techniques for enhanced target detection on the ground and in the air.

The phosphor bronze reticle, or image chopper, illustrated above was developed by Ramo-Wooldridge. It indicates a marked stride in space filtering discrimination concepts, and is used for target signal enhancement in guided missiles, anti-aircraft fire control and air collision warning applications.

The reticle is used in the focal plane of an infrared optical system and is rotated to chop the target image for the desired space filtering. It is also employed in time filtering, such as pulse length discrimination, or pulse bandwidth filtering.

Space filtering is critical to infrared systems, because of its ability to improve the detection of objects located in the midst of background interference. In a manner similar to that used in the modification of electronic waveforms by electrical filtering, space filtering enhances the two-dimensional space characteristics of a target. The size and features of the target are highlighted and the undesired background eliminated.

Scientists and engineers with backgrounds in infrared systems—or any of the other important areas of research and development listed below—are invited to inquire about current opportunities at Ramo-Wooldridge.

Electronic reconnaissance and countermeasures systems
Analog and digital computers
Air navigation and traffic control
Antisubmarine warfare
Basic research
Electronic language translation
Information processing systems
Advanced radio and wireline communications
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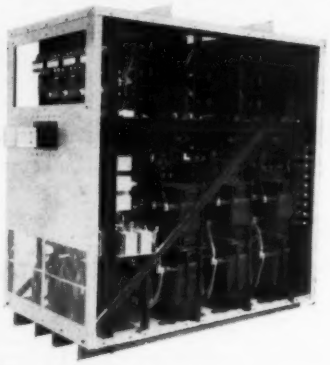
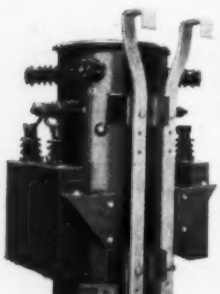
HEVI DUTY

IN STEP
with tomorrow's
stepped-up
DEMANDS

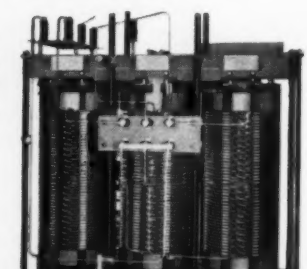
DRY TYPE TRANSFORMERS,
CONSTANT CURRENT REGULATORS
AND SATURABLE REACTORS



CONSTANT CURRENT REGULATOR used in an industrial electrochemical process.



CONSTANT CURRENT REGULATOR for street, subway and airport lighting.



DRY TYPE TRANSFORMER, 300 KVA, for unit substation. Other transformers are available from 5VA to 2000 KVA as well as Saturable Reactors from 25VA to 500 KVA.

HEVI-DUTY ELECTRIC COMPANY

MILWAUKEE 1, WISCONSIN

Harold E. Koch, '22, *President*
Elton E. Staples, '26, *Vice President*
Chester Meyer, '36, *Assistant Secretary*

TREND OF AFFAIRS

(*Continued from page 252*)

Street, and Vassar Street; and mentioned some specific projects that will affect M.I.T.'s planning, such as the projected belt route and the extension of Route 2.

Final speaker of the evening was Robert A. Dudley, '51, a research associate in the Department of Physics, who spoke on radium poisoning. The use of radium in luminous dial paints and in medical "treatment" early in this century resulted in death and tragic injury for many. Dr. Dudley described the subsequent study and detective work currently being carried on in M.I.T.'s Radioactivity Center by means of which the analysis of the effects on those who were so exposed years ago has produced an important fraction of our knowledge about toxicity of long-continued irradiation of the human body – a subject of crucial interest as we enter the atomic era. He described how data from this vital "experiment" inadvertently started several decades ago are now being collected and studied at M.I.T. He also described many of the problems in connection with this work such as finding the persons who had received these internal doses of radium decades ago; finding ways of measuring the amount of radium in the body and extrapolating to an estimate of the original radium burden which had existed initially; determining the distribution of the radium in the body; and determining the medical effects, such as damage to blood-forming organs, malignant tumors, pathological fractures, and bone destruction.

Twenty-five Years Ago This Month . . .

■ During March, 1934, inhabitants of southern Illinois and Indiana recovered 28 of a total of 40 small red rubber balloons which had been released on February 28 – "a cold, still day" – by members of the Institute's Division of Meteorology from Lambert Field Airport, St. Louis, Mo.

Directing the launching had been Professor Carl G. A. Rossby, and the balloons, each about four feet in diameter when inflated, and carrying delicate recording instruments in shock-absorbing bamboo frames, had been released in accordance with careful weather forecasts prepared at Technology by Professor Hurd C. Willett and Jacob Bjerknes, the distinguished Norwegian meteorologist of "polar front" authority.

In The Review's words, "These travelers to the stratosphere rose many miles above the earth, and finally burst in the rarefied air of that region. The fluttering fragments of broken rubber were relied on to break the instruments' speed of descent. Each bore an identification tag offering a reward to the finder, providing the instruments and their records were not tampered with. . . .

"A mid-continent location for the experiments was chosen in the hope that most of the instruments would be found on land. To carry out the study in New England, where the prevailing winds are from the west,

(*Concluded on page 256*)

1,600,000 Bell Telephone Share Owners

Most are small share owners. Women are the largest group.
More than 250,000 are Bell telephone employees.

The Bell System is an outstanding example of American democracy in business.

Millions of people use telephone service. 735,000 people work for the Bell companies. More than 1,600,000 people own A.T.&T. stock.

The owners of American Telephone and Telegraph Company stock are people in all walks of life.

Most of them are small share owners. No one individual owns as much as 1/30th of one per cent of the stock. Many thousands own five and ten shares. About half own fifteen shares or less.

Women are the largest group and hold the most stock. Over 250,000 of the share owners are Bell telephone employees.

Some 85 per cent of all the shares are owned by individuals. In addition to these direct owners of A.T.&T. securities, many millions of other people have an important, beneficial interest through the holdings of their insurance companies, pension funds, investment companies, unions, savings banks, etc.

The total of direct and indirect owners represents the great majority of all the families in the country.

A.T.&T. share owners, and the owners of A.T.&T. bonds, are the financial foundation of our ability to serve. For without the money they have put in the business you would not have the quality and quantity of telephone service you enjoy today. Nor would there be work and wages for 735,000 employees.

OWNERSHIP IS WIDESPREAD. A.T.&T. share owners live in cities, towns and on farms, in 22,000 communities throughout the country. About 450,000 of the shares are in two names, generally husband and wife. Many hundreds of hospitals, churches, libraries and charitable organizations are among the holders of A.T.&T. stock and bonds.

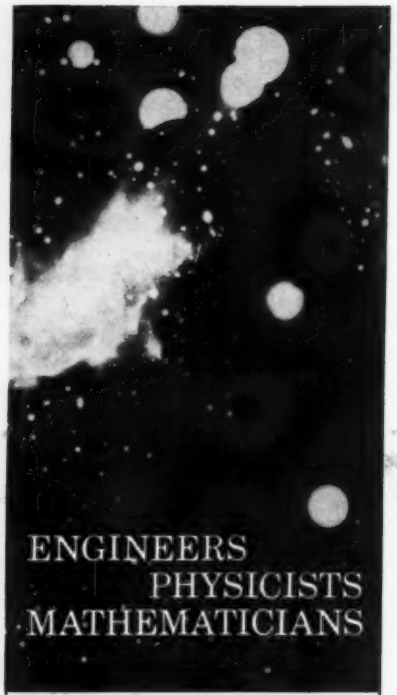
Obviously, investors will continue to supply capital in the amounts required for present and future needs only if they can expect the Bell System to earn a return on the money they invest that is reasonable in comparison with the earnings rates of other companies and industries.

So telephone progress, and the advantage to all that comes from pushing ahead, begins with good earnings and our faith that Americans want good and improving service at prices which allow a fair profit.

That is the way of life which in our country has stimulated invention, nourished enterprise, created jobs, raised living standards and built our national strength.

As long as we live by this principle—and earnings are sufficient to enable us to carry it out—the future of the telephone is almost limitless in possibilities for service to you.

BELL TELEPHONE SYSTEM



Douglas diversification affords broadened opportunities, combined with stability and security.

Engineering at Douglas is divided into three basic areas ... missile and space systems, transport aircraft and combat aircraft. In these military *and commercial* categories, each advancing beyond present frontiers of achievement, engineers and scientists can progress to the limit of their capabilities.

In addition, supervisory and executive openings are filled from within the company. Many of the top executive officers at Douglas are engineers who have moved right up to assume wide responsibility.

We are interested in engineers with backgrounds in other fields as well as avionics, aircraft and missiles.

For further information write to Mr. C. C. LaVene, Douglas Aircraft Company, Inc., Santa Monica, California.
Section N.

the most respected name in aircraft, missile and space technology

TREND OF AFFAIRS

(*Concluded from page 254*)

probably would have resulted in loss of most of the balloons at sea."

Preliminary readings of the first meteorograph received back at the Institute indicated that the balloon had risen to a height of 10.7 miles, where the temperature was recorded as —64 degrees Fahrenheit.

■ It was announced in The Review that Professor *Jerome C. Hunsaker, '12,* Head of the Department of Mechanical Engineering, had had honorary fellowship conferred upon him by the Institute of the Aeronautical Sciences. He was at the time retiring from the presidency of that Institute, the incoming officers of which included *Donald W. Douglas, '14,* as Vice-president, *Edwin E. Aldrin, '17,* as Treasurer, and *Lester D. Gardner, '98,* as Secretary.

■ Kudos came also to other Alumni in the form of new responsibilities, namely: . . . to *Francis P. Sears, '90,* as President of the Columbian National Life Insurance Company; . . . to *Elbridge C. Jacobs, '96,* as State Geologist of Vermont; . . . to *Arthur C. Willard, '04,* as President of the University of Illinois; . . . to *Alfred H. Schoellkopf, '15,* as President of the Niagara Hudson Power Corporation; . . . to *Lammot du Pont, '01,* and *Frank B. Jewett, '03,* as newly elected Life Members of the Institute's Corporation.

Space Environment Symposium

■ Now that the Institute's Department of Aeronautical Engineering has become the Department of Aeronautics and Astronautics, courses are being revised and people are being reoriented toward education and research regarding space. As part of this program, a Space Environment Symposium got under way in February and will continue through the spring.

Lecturers in this symposium in March will be Gerard de Vaucouleurs and Fred Whipple of Harvard and Professor Millett G. Morgan of the Thayer School of Engineering at Dartmouth. In April, Professor Robert Leighton of the California Institute of Technology, Professor Clyde Tombaugh of New Mexico A. and M. College, and Richard Herzog and Murray Zelikoff of the Geophysics Corporation of America will be heard. Professor Harold C. Urey of the University of California and Herbert Friedman of the Naval Research Laboratory will conclude the series in May.

Mid-Year Degrees

■ Diplomas have been awarded to 235 students at mid-year by M.I.T. The students represent 33 states and 23 foreign countries. The largest number of foreign students to receive diplomas came from India, and the largest number of graduates from the United States were those from Massachusetts.

There were 180 graduate degrees awarded and 48 undergraduate, with seven students receiving both bachelors' and masters' degrees.

HOW BIG CAN A SMALL BUSINESS GROW?

Yesterday a one-man business; today a thriving, growing organization; tomorrow . . .? There seems to be no limit to the future of the alert, small businessman. Sometimes, though, ability and determination are not enough. Sound financial planning must precede larger plant facilities, new equipment, bigger inventories. If your business has reached a crossroad where the high road to growth requires experienced financial advice, you're welcome at Second Bank-State Street. These officers in our Credit and Loan Division are ready to go to work for you:

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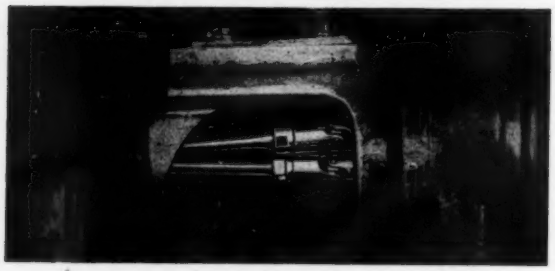
Solving a breakage problem AT CLOSE QUARTERS



The manufacturer of this button-drilling machine had a tough problem: the universal joints on these parallel shafts carried such a torque load there were frequent complaints of breakage . . . yet the close centers prohibited use of a larger joint. **The solution** was a Curtis Universal Joint of the same size but higher torque.

This is only one of many problems solved by Curtis Joints — size for size the strongest universal joints designed for industry. Selected materials, precision engineering, and over 30 years' experience manufacturing universal joints make them that way.

14 SIZES ALWAYS IN STOCK
⅜" to 4" O.D.
(6" joints on special order)

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WHERE WE STAND IN SPACE

(*Continued from page 246*)

accelerators of nuclear physics. These accelerated particles will give a reaction thrust. One also can use nuclear fusion to develop high-temperature, charged plasmas which in turn are accelerated by electronic means. One can also employ light particles themselves in a reaction motor. Unfortunately, all these proposals are at a very early stage. A long-term research program is required before one can say anything about their future.

Guidance

Though most people today have a fairly good concept of the performance of rocket vehicles, their ideas about guidance of these vehicles in space are not clear. A good reference point for the guidance accuracy of space vehicles is the accuracy obtainable in firing ballistic missiles. At a range of 5,500 nautical miles, or about one-quarter of the way around the earth, an error of one foot per second in the velocity at the end of burning of the final rocket will cause an error in hitting a target of about one nautical mile. This represents an error of about one part in 24,000, since missiles require about 24,000 feet per second to reach that range. One can suspect that such an accuracy is the objective of military ballistic missiles, if they are to be militarily useful. One can also suspect that, in the early stages of development, that accuracy has not yet been fully attained.

What does such an accuracy represent with respect to some of the simpler nonmilitary space missions? In establishing a satellite at an altitude of 1,500 miles, an error of one foot per second in the orbital velocity will cause the orbit to depart from circularity by about one mile. That same accuracy of one foot per second in final velocity would cause a miss of something less than 100 miles in shooting at the moon; in shooting at Mars or Venus, the order of 20,000 to 25,000 miles; in shooting at Jupiter, the order of 65,000 nautical miles. Thus for these one-shot type of space missions, the accuracy of guidance obtainable in ballistic missiles' guidance systems gives us a good space-guidance capability.

The guidance of most of the space missions that one now deals with is initial guidance; the guidance apparatus works only during the first portion of the flight. The equipment used is either of the inertial type or of the radio type. Inertial guidance involves accelerometers and gyroscopes to calculate the deviation from a preset course and to adjust the direction of the thrust to correct for the deviation. Radio guidance employs radar or radio triangulation and Doppler equipment to measure the path of the vehicle. A radio command signal corrects errors which develop in the flight path. With regard to these equipments, the developments already under way for the ballistic missile field clearly assist in the space mission field.

In the future, however, guidance will be required which can be used in the mid-course of the flight of a space vehicle. Star trackers, radio or radar equipment to measure the direction to planets, extremely accurate atomic clocks, additional inertial elements, and horizon-scanning devices will be needed.

(*Continued on page 260*)

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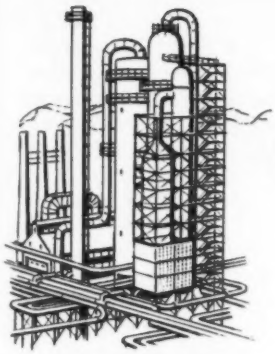

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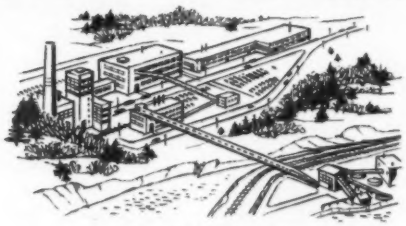

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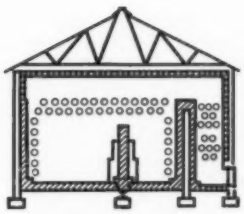

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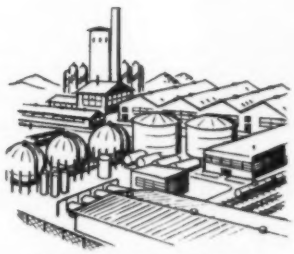

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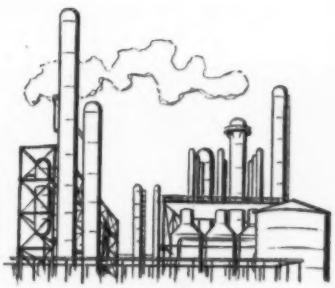
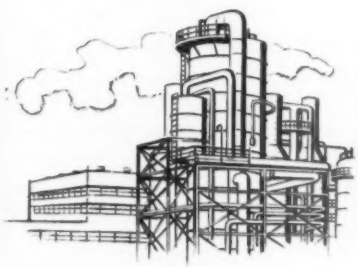


Petrochemical Plants



Chemical Plants

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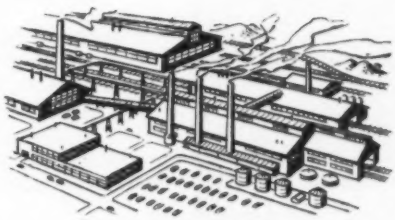

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WHERE WE STAND IN SPACE

(*Continued from page 258*)

Finally, there is the terminal guidance problem. We have not developed terminal guidance equipment for either ballistic missiles or true spacecraft. For the most part, we have been content to depend upon the stability of the re-entry vehicle to insure that it does not deviate too much from its initial course as it enters the atmosphere. Some day, terminal guidance must be developed for more complicated missions.

Communication, Tracking, and Observation

When the Russian artificial asteroid was established in orbit around the sun, the tracking was done by radio-direction finding, using the radio transmissions from the vehicle itself. These transmissions continued for 60 to 70 hours. By that time the vehicle was past the moon and well started on establishing its orbit around the sun; the distance was somewhere between 300,000 and 400,000 miles. Thus, communication and tracking were performed out to that distance. That is quite an achievement, but clearly it indicates some of the shortcomings of existing equipment. For extremely long-range space missions, out to the regions of the other planets, communication equipment must continue for much longer periods.

It does not take much imagination to figure out what engineering problems are associated with communication and tracking by means of radio emissions from the vehicle itself. Longer-life batteries or better auxiliary power sources, more reliable components, and smaller, lighter-weight components are needed.

Can the vehicles also be observed and tracked by other means than by radio-direction finders employing radio emissions from the vehicles themselves? Of course they can, if they are not too far away. Radar sets on the surface of the earth can track inert objects. The range at which this can be accomplished at the present time, however, is only of the order of a few thousand miles. So, only the vehicles close to the earth are susceptible to tracking observation by radar. The same can be said for visual observation by telescopes unless there is on the space vehicle an accurately pointed mirror to reflect sunlight back to the telescope.

Manned Space Flight

Manned space flight for whatever application presents unique engineering problems. Most of these are associated with the limitations in acceleration which

(*Continued on page 262*)

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WHERE WE STAND IN SPACE

(*Continued from page 260*)

a man can withstand, and the environment which a man must have to maintain life.

The first of these engineering problems is a characteristic of rocket takeoff. The large spacecraft now conceived employ liquid-propellant rockets for the principal booster stages. Experience indicates that these are somewhat unreliable. There is a high percentage of failures at or near takeoff. Thus, the first safety problem is to ensure a method of survival even if an accident occurs during the boost period. The current plan to ensure greater safety for a manned capsule at takeoff is to employ a reliable solid-propellant rocket as an auxiliary safety rocket. Such a rocket, in event of failure of the main booster, can propel the manned capsule sufficiently high in the air so that the parachute and other escape mechanisms can be activated.

Failures of liquid-propellant rockets are not usually explosive; rather, there is only a fire of rapid build-up. There is little danger of shattering the manned capsule with an abrupt explosion of a liquid-propellant rocket. In the future, when and if large solid propellants are used as the initial booster stages, though the chance of failure will be less than for liquid-propellant motors, there will be a greater danger that a true explosion will occur. This characteristic of solid-propellant rockets may rule them out as boosters for manned space vehicles. Experience has shown, however, that they are more reliable and simpler to operate than liquid-propellant rockets.

The accelerations encountered by the vehicle during the burning period must be kept within the limits which a man can stand. Many experiments now indicate that a man can stand about 10 g. acceleration for the length of time of the boosting phase, say of the order of one minute. This is just about the peak acceleration achieved in a multistage rocket. The acceleration of the manned capsule builds up from a small value at takeoff, slightly over 1 g., to fairly large values at the end of the burning of a given stage, because, though the thrust of the rocket stays constant, the mass of the vehicle drops with the rapid burning of fuel. In a staged vehicle the final acceleration stays within tolerable limits.

Analysis of the decelerations to which a vehicle is subjected as it re-enters the earth's atmosphere indicates, however, that the accelerations will far exceed

(*Concluded on page 264*)

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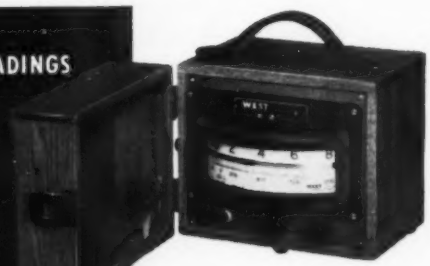

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WHERE WE STAND IN SPACE

(*Concluded from page 262*)

those which a man can stand unless the re-entry is made at a very low angle from the horizontal. Other engineering problems are introduced by such re-entry trajectories. As one can easily see, such a low-angle re-entry trajectory through the atmosphere is a very long one; many thousands of miles are traversed through the atmosphere. This makes landing and recovery at a specific point a much more difficult job to accomplish.

Another problem of manned re-entry into the earth's atmosphere is associated with the great heating rate of a high-speed re-entry. This problem was met first, of course, in ballistic missile design. Now a number of techniques have been developed to permit re-entry of vehicles through the earth's atmosphere at these very high speeds without having them burn up. One is to employ a thick shielding skin to absorb much of the heat. Another is to use a material on the skin which slowly dissociates and evaporates, using the latent heat of vaporization in absorbing large amounts of heat. In the future, no doubt, these and other techniques will solve the heating problem.

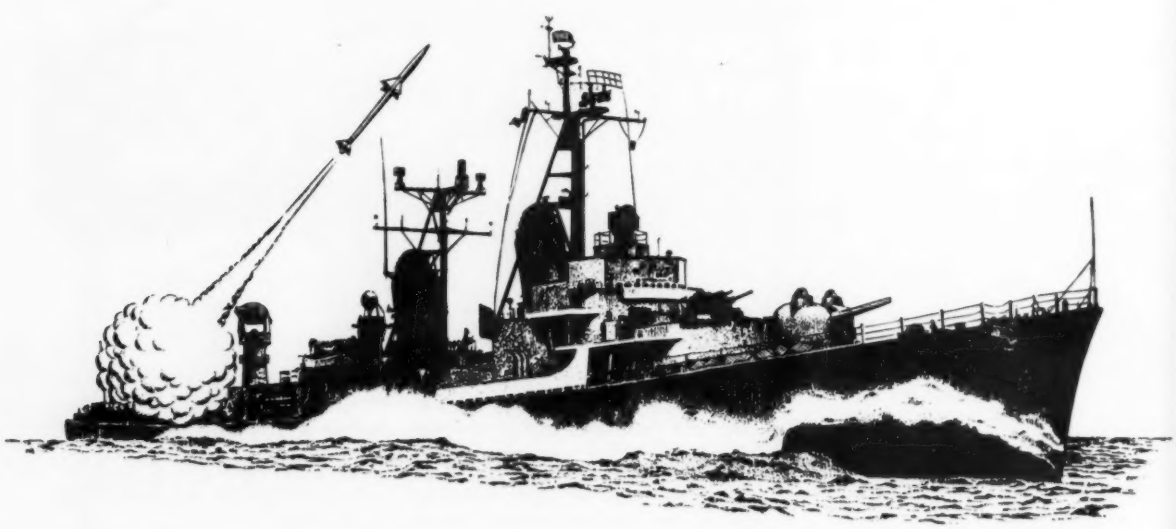
Radiation constitutes another much talked-about hazard to manned space flight. A great deal more study is needed to understand the full biological implication of a heavier cosmic-ray dosage.

Recently in satellite experiments, new space radiations were discovered which consisted of high-energy particles, either electrons or protons, which had established stable orbits around the earth. This radiation, known as Van Allen radiation (as shown on page 245), can be serious because high-energy, charged particles create soft x-rays when they impinge on the space vehicle. There seem to be two major belts of high-intensity radiation, with lesser intensity in between, concentrated around the equatorial plane.

If this radiation proves to be sufficient in intensity and character to be damaging to humans, it will be possible to avoid it by the selection of proper paths, avoiding the high-intensity belts. Long-range space missions can go out on a polar route, though such routes are more difficult than an equatorial route from the standpoint of propulsion. Shorter-range manned missions, such as satellite missions, can be arranged so that the trajectory stays below the first of these two radiation belts.

There are, of course, many other problems with respect to proper living conditions, food, and so on, on manned space flight for extremely long missions. By the time we have the capability of getting a man out into space and back through the atmosphere safely, however, we will have had plenty of opportunity to work on these environmental problems.

We can accomplish many of the desired space missions soon, simply by employing our known rocket, guidance, tracking, and vehicle-design capabilities. But if we are to have a long-term space program, one which involves more and more complex missions, with bigger vehicles going to more remote objectives, we will need new developments which are only in the idea stage today.



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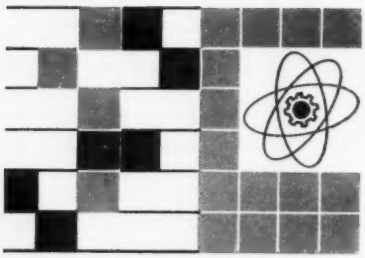

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COLLEGE ADMISSIONS — II

(Continued from page 250)

entering class, he does not welcome such queries from interested persons as: "How can I insure the admission of this young man?" The last thing the Admissions Office wants to do is "insure" anyone's admission in advance. It has a responsibility of intercomparison and selection and will want to wait until all the evidence is in before making it.

College admissions practice in the United States in recent years has given rise to two devices which M.I.T. has not adopted. One which is in current use among the Eastern women's colleges is the "early decision" plan by which a student whose record is strong may, by agreeing to apply only to a single college, gain an early admission in the fall of her senior high school year, subject only to continuing a good record through the year. The other device is the practice of some colleges of visiting schools in the early fall and, after interviewing applicants, classifying them into: Class A, who are virtually assured of admission if they maintain good records; Class B, who are uncertain; and Class C, who will probably not be accepted.

M.I.T. has not adopted these plans because we set a very high value on making the most careful possible selection and on minimizing failures and drop-outs to the greatest possible extent. We do not want arrangements with favored schools which might unfairly lessen the chance of students from more remote or less well-known schools, or of students who apply later. Furthermore, selection for our type of work depends heavily on ability in mathematics and science; therefore we need the additional evidence in the form of mathematics and science test scores which normally reach us in April of the senior year and are seldom available earlier. We also like to get the school marks for the first half of the senior year in school. We feel that the human cost of failures in college is so great that it is far more important to minimize these as much as possible in preference to the alternative, also laudable, of ending the uncertainty as soon as possible. It would be a pleasant world if all uncertainty could be eliminated and we could tell everyone at the earliest possible date just what he wants to hear. This objective, however, is not compatible with the more important one of minimizing failures. We therefore wait until all the evidence is in and send out most of our notices of admission about the first of May. Both schools and students have indicated in almost every case that they appreciate the force of this argument. We give applicants until May 30 to decide whether to accept an offer of admission, so as not to put them under pressure of time.

It is interesting to consider some of the typical questions which visitors ask of admissions officers. Perhaps the most frequent one is, "What are my chances of admission?" or, "What are my chances of getting a scholarship?" The answer to these questions almost always is: "We don't know enough about you at this stage and will have to get a great deal more evidence before we can answer the question." Admis-

(Continued on page 268)

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COLLEGE ADMISSIONS — II

(Continued from page 266)

sion, and to a still greater degree, financial aid, is a competitive matter and admissions committees want to make sure they have looked over all the evidence and intercompared all the candidates as fairly as possible before they announce their decisions. So the answer to these questions is: "By all means put in an application, let us have all the necessary data and then we will give an answer as soon as possible."

A favorite question of parents is, "Is he too young to enter college?" The interesting thing about this question is that if you ask almost anyone whether he would have done better in college if he had been two years older when he entered, he will invariably say yes. The difficulty is that the same could be said of almost any experience in life; if we had been a little older when we underwent the experience, we certainly could have dealt with it more effectively. Therefore we come up against the impasse that one cannot wait indefinitely for all the experiences in one's life to start. Very often the best place for this growing-up process to occur is in school or college. So we come back to the conclusion that if a student shows a reasonable probability of having sufficient maturity to plan his own time in college, and come through with an acceptable result, he will probably be better off there than somewhere else, in terms of his long-range development. It is, nevertheless, true that some students are immature enough so that they would do better to get a job or enter the service for a couple of years before their college experience begins.

Another favorite question on the part of students and parents is: "How many applications do you have?" – immediately followed by the second question: "How many do you accept?" The unspoken assumption that lies back of this inquiry is always that the probability of acceptance here is a direct function of the fraction of applications that are actually accepted. This is true only in a very artificial sense. The student who is well prepared, who has a good school record and test scores, and who gives sufficient indication of maturity to indicate that he can probably come in and do well, is likely to have no difficulty in being admitted even though the number of applications is very large. On the contrary, the student who looks marginal, or whose success is definitely uncertain is probably not going to obtain acceptance even though there is little pressure for admission. This is another way of saying that the most important determinant of the quality of an entering class is not the number of applications, but how good these applications are. If our class is to number 900 and we have 901 really topnotchers applying and anxious to enter, that is all the selection we need. On the other hand, 10,000 applications from people of mediocre qualifications do us little good.

Then, of course, there is the student who says, "How high must my marks be?" The answer to this always is, "You should feel free to get them up just as high as you wish." It is true that high school marks are important indicators of probable future success in college, but they must always be studied in relation to other evidence, such as test scores, and comments from teachers and others who are in direct contact with the student and have seen how he performs.

Similarly, extracurricular activities have a real place in the whole problem of selection. Students

(Concluded on page 270)

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COLLEGE ADMISSIONS — II

(Concluded from page 268)

like to ask how much do these activities "count." The answer of course is, they do not "count." They are an element in the whole judgment that must be brought to bear, but this judgment is not arrived at by a counting process. We are not interested in students who accumulate long lists of clubs and other organizations of which they are members in high school – least of all if this is done to impress admissions officers. The student who has taken a really responsible part and shown initiative in some other activity in high school, no matter how minor, is a far better risk for college than the "joiner" who has little to his credit but being a member. So we look especially for responsible statements from school people who know in detail how active and energetic a student has been and how far he has been willing to broaden his interests and efforts beyond the minimum round of academic work.

There are still many unsolved problems in connection with the selection of students for higher education; these are likely to be intensified at M.I.T. because of the exacting nature of the curriculum. It is significant, however, that students who drop out, either through formal disqualification or for other reasons, do not lack in intellectual ability, nor do most of them lack adequate preparation. Their trouble stems rather from emotional problems which result in poor motivation. Until we gain a deeper understanding of the development of adolescents, it will be difficult to reduce further the percentage of dropouts. We know little of the psychological forces that turn one student into a purposeful worker and another into an aimless drifter. We cannot always distinguish the "late bloomer" from the nonbloomer.

Tests are a useful, in fact, an indispensable aid to intelligent selection; but tests deal only with peripheral aspects of behavior. The energy and drive that lead to great achievement have their roots deep in the vital energies of the soul. The last half century in psychology has given us glimpses of this turbulent inner world, but we are still far from understanding it. And so for the foreseeable future, it seems probable that efforts to solve these problems of forecasting human behavior will remain in large measure empirical and will lie in the domain of judgment rather than of science.

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and the prophet replied:
*"It is well to give when asked, but it is better to give unasked, through understanding."**

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The tale is told of Almustafa, the prophet, who, having awaited for many years the ship that would return him to the place from whence he came, was making the final descent to the shore when the folk of Orphalese crowded about him. They besought him before departing to "disclose us to ourselves, and tell us all that has been shown you of that which is between birth and death."

With words of wisdom, an answer appropriate was given to the woman holding a baby, to the ploughman, to the merchant. Begged one, "Speak to us of GIVING," and the prophet replied:

> "It is well to give when asked, but it is better to give unasked, through understanding;
> And to the open-handed the search for one who shall receive is joy greater than giving. All you have shall some day be given;
> Therefore give now, that the season of giving may be yours and not your inheritors'."

Through the years the prophet's words have held true, for even today he who "through understanding" includes the MASSACHUSETTS INSTITUTE OF TECHNOLOGY as a beneficiary in his will can experience thereby a two-fold satisfaction. The successful culmination of his search for a worthy recipient and the anticipated results his generosity will assist in accomplishing. These satisfactions give an added value to the span of man's days and project his usefulness to his fellowmen far into the future.

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But the search, the finding, and the anticipated accomplishments are not enough; for without the properly-worded record, man's plan for the future may go awry. Hence the prophet's importuning, "—give now," should be heeded. The giving need not be an immediate physical transaction, for written directions replace the spoken word when the speaker is no longer present, and a donor can frequently make by will a gift which is larger than he can make while living. Truly, *"it is well to give when asked, but it is better to give unasked, through understanding."*

A booklet "Gifts by Will," outlining different forms of bequests to M.I.T., is available to you or to your attorney by writing to:

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* "The Prophet" by Kahlil Gibran

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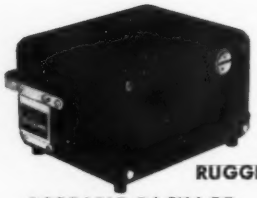

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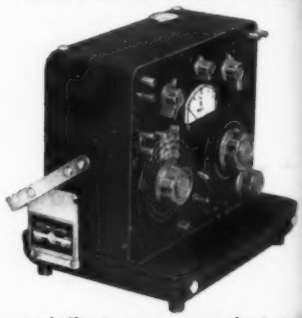

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